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EFEITOS DA FAMILIARIDADE EM JULGAMENTOS DE DURAÇÃO

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RESUMO

A familiaridade tem o efeito de dilatar a nossa experiência subjetiva da duração de um estímulo ou evento. Este efeito tem sido essencialmente associado a dois níveis de alterações no processamento de propriedades não-temporais do estímulo: a eficiência no processamento dessas informações, e a experiência subjetiva de fluência desse mesmo processamento. Os trabalhos desenvolvidos nesta tese tiveram como principal objectivo contrastar as duas explicações teóricas que se sustentam nessas vias de processamento, mas até aqui sem fundamentação empírica. Nomeadamente, uma hipótese atencional, enquadrada em modelos dedicados de processamento de informação (i.e., relógio-interno) no campo da percepção de tempo, e uma hipótese atribucional de fluência, enquadrada em modelos generalistas de decisão e julgamento. Num primeiro estudo meta-analítico, integrando a literatura experimental sobre o efeito da familiaridade, demonstrámos a sua consistência e validade. Além disso demonstramos que este é moderado pela duração objectiva dos estímulos suportando processos de interferência exógena na atenção seletiva à informação temporal. No entanto o efeito não parece ser moderado por tarefas concorrentes. Dados de um segundo estudo experimental oferecem porém evidencias de efeitos de distribuição de recursos cognitivos com um papel no processo associado ao efeito de familiaridade. Isto dado o papel que a sensibilidade ou discriminação temporal exerce sobre o efeito (apenas previsto pelos modelos de relógio-interno para alterações associadas à distribuição de recursos atencionais). Adicionalmente, os dados do estudo meta-analítico sugerem que os efeitos da familiaridade ocorrem quando a informação temporal é mais difícil de discriminar, o que está concordante com o uso metacognitivo da experiência de fluência para desambiguar a informação do julgamento corrente. Num terceiro estudo, corroborámos a hipótese-atribucional para o efeito de familiaridade nos julgamentos de duração ao demonstrar que este é mediado pela atividade dinâmica do músculo zigomático major associado a afetos positivos próprios da experiência de fluência. Neste estudo os indicadores atencionais (i.e., atividade do corrugador superciliar e da frequência cardíaca) não parecem estar associados à emergência do efeito. Adicionalmente, testamos a hipótese do efeito de familiaridade poder ser explicado por modelos puros de fluência perceptiva. Para o efeito contrastámos meta-analiticamente efeitos de familiaridade, que agrega componentes de fluência perceptiva e conceptual, com manipulações puramente perceptivas. Como esperado o efeito é replicado com as manipulações de fluência perceptiva. No entanto, constatámos que outros indicadores derivados dos pressupostos dos modelos de fluência, nomeadamente, efeitos de discrepância e de correção da atribuição, se verificaram apenas para a fluência perceptiva, sugerindo que os efeitos de familiaridade não se resumem a efeitos de fluência. Tomados em conjunto estes dados sustentam que o efeito de familiaridade emerge por uma convergência de processos que ocorrem através de múltiplas vias. Apontamos portanto para a necessidade de uma complementaridade dos modelos na compreensão dos processos subjacentes ao efeito da familiaridade.

ABSTRACT

Familiarity has the effect of expanding our subjective experience of the duration of a stimulus or event. This effect has been essentially associated with two levels of changes in the processing of non-temporal properties of the stimulus: the efficiency in the processing of this information, and the subjective experience of fluency of this same processing. The work developed in this thesis had as main goal to contrast the two theoretical explanations that are based on these processing routes, but until now without any empirical bases. Namely, an attentional hypothesis, framed in dedicated models of information processing (i.e., internal-clock) in the field of time perception, and an attributional hypothesis of fluency, framed in generalist models of decision and judgment. In a first meta-analytic study, integrating the experimental literature on the effect of familiarity, we have demonstrated its consistency and validity. In addition, we demonstrate that it is moderated by the objective duration of stimuli supporting processes of exogenous interference in selective attention to temporal information. However, the effect does not seem to be moderated by non-temporal concurrent tasks. Data from a second experimental study, however, provide evidence of cognitive resource distribution effects with a role in the process associated with the familiarity effect. This is given the role that temporal sensitivity or discrimination exerts on the effect (only predicted by the clock-internal models for changes associated with the distribution of attentional resources). In addition, data from the meta-analytic study suggest that the effects of familiarity occur when temporal information is more difficult to discriminate, which is consistent with the metacognitive use of the fluency experience to disambiguate the central information in the judgment at hand. In a third study, we corroborated the attributional hypothesis for the familiarity effect in duration judgments by demonstrating that it is mediated by the dynamic activity of the zygomaticus major muscle, which is associated with positive affect of the fluency experience. In this study, attention indicators (i.e., corrugator supercilli activity and heart rate) do not appear to be associated with the emergence of the effect. Additionally, we test the hypothesis that the familiarity effect can be explained by pure models of perceptual fluency. For this purpose we meta-analytically contrasted the effects of familiarity, which aggregates perceptual and conceptual fluency components, with purely perceptual manipulations. As expected the effect is replicated with perceptual fluency manipulations. However, we found that other indicators derived from the assumptions of fluency models, namely discrepancy effects and correction of attribution, were verified only for perceptual fluency, suggesting that familiarity effects are not limited to fluency effects. Taken together these data hold that the familiarity effect emerges through a convergence of processes that occur through multiple paths. We therefore point to the need for a complementarity of models in understanding the processes underlying the effect of familiarity in duration judgments.

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Familiarity effects in duration judgments: A meta-analytic review

Secção I

Introdução

"*A clock is a little machine that shuts us out from the wonder of time*."

Susan Glaspell, "*Tickless Time*"

A nossa capacidade de perceber o tempo é muito precisa, o que é fundamental em muitos aspectos da cognição que se desdobram no tempo e em praticamente todos os comportamentos, desde a realização de ações simples a complexas, como atravessar uma rua movimentada ou coordenar as nossas interações sociais (Buhusi and Meck, 2005; Gibbon et al., 1997; Grondin, 2010). No entanto, a experiência subjetiva do tempo pode ser dramaticamente alterada pela recorrência desses eventos, ou pela familiaridade dos estímulos que preenchem o desenrolar desses eventos. Este fenómeno que se caracteriza por uma expansão da duração percebida, tem sido repetidamente verificado ao longo da extensa literatura sobre distorções temporais no campo da percepção temporal. Contudo pouco relevo se tem dado no sentido de explorar empiricamente quais os mecanismos subjacentes a este fenómeno, além de enquadrá-lo num modelo compreensivo já existente.

Na revisão de literatura sobre o tópico encontramos este enquadramento do fenómeno quer em modelos que visam explicar os mecanismos de percepção de tempo quer em modelos generalistas que visam perceber os enviesamentos de julgamento e decisão.

Os modelos de percepção do tempo chamam a atenção para o facto de apesar do tempo ser uma dimensão física contrasta com outras dimensões físicas básicas (como a visão e audição), por não existir um sistema sensorial dedicado para o processamento e representação explicita do tempo (Ivry & Schler, 2008; Coull, Cheng, & Meck, 2011). Em vez disso, o tempo subjetivo sugere ser uma abstração, uma construção ou epifenómeno da mente (Allman, Yin, & Meck, 2014; Grondin, 2001, 2010; Macar & Vidal , 2009). Contudo, o tempo subjetivo tem uma relação com o tempo objectivo, sendo esta uma relação linear muito precisa, e similar em termos psicofísicos a outras dimensões sensoriais (Allman, Teki, Griffiths & Meck, 2014). Neste sentido foi proposto a existência de um mecanismo semelhante a um "*relógio-interno*" (Creelman, 1962; Church, 1984; Treisman, 1963) com origens neurobiológicas (Coull, Cheng & Meck, 2011). O desafio do campo da percepção de tempo é identificar o mecanismo pelo qual o "*relógio-interno*" funciona, e como este pode explicar as distorções causadas por uma variedade de fatores cognitivos. Assim, este modelo oferece-se como explicação para as distorções na percepção do tempo promovidos pela familiaridade. Fá-lo assumindo que a familiaridade interfere com os mecanismos atencionais que suportam o funcionamento do relógio interno (e.g., Chastain & Ferraro, 1997; Hochhaus, Swanson, & Carter, 1991; Warm, Greenberg, & Dube, 1964).

Mas a nossa percepção de tempo, é usualmente reflectida em julgamentos ou decisões sobre a duração de um evento ou estimulo (e.g., Grondin, 2010). Abordagens generalistas sobre processos de decisão e julgamento, enquadram os enviesamentos de julgamentos de duração não os distinguindo de outras dimensões ou variáveis não-temporais. Uma destas abordagens baseada em processos metacognitivos de atribuição, serviu na literatura para explicar as distorções temporais promovidas pela familiaridade do estímulo que variam na experiência subjetiva de fluência como este é processado (e.g., Kleider & Goldinger, 2004, Masson e Caldwell, 1998; Reber et al., 2004).

A literatura nunca procurou testar experimentalmente os pressupostos dos modelos no sentido de validar as explicações para este fenómeno, e nem mesmo, a confrontação teórica entre estes. A literatura limita-se a enuncia-los, ficando-se por se saber a sua validade explicativa.

A presente tese tem como objectivo fornecer um mais claro entendimento de como e de porquê a familiaridade influencia os julgamentos de duração. Para tal, revemos a literatura associada ao campo procurando sistematizar os pressupostos dos dois modelos. No capitulo I revemos a literatura evidenciando o efeito e em que condições ocorre. Nos seguintes capítulos revemos as duas abordagens teóricas que têm sido propostas para explicar este efeito, destacando diversos subprocessos, pressupostos por estes, que aferem sobre a validade explicativa do efeito. A abordagem empírica proposta é a de delimitar o efeito de familiaridade em julgamentos de duração e a de testar alguns dos pressupostos dos modelos com vista a esclarecer a sua contribuição na explicação do fenómeno. Com este objectivo global, procuraremos perceber as dinâmicas encontradas entre o efeito de familiaridade aqui definido (estímulos previamente expostos), o efeito promovido pela fluência perceptiva e o efeito promovido pela repetição de estímulos dentro do mesmo contexto (efeito de repetição).

A primeira abordagem é meta-analítica onde não são sistematizados apenas os resultados dos estudos reportados na literatura, mas são também testadas novas hipóteses, com esses mesmos dados (comparando diferentes conjuntos de estudos). Essas hipóteses definem possíveis moderadores do efeito, e esses derivam dos próprios modelos servindo, assim de indicadores de algum dos seus pressupostos.

Apresenta-se de seguida dois artigos que testam experimentalmente alguns dos pressupostos dos dois modelos. O primeiro adiciona a medida de sensibilidade aos paradigmas de percepção de tempo por considerar que é este parâmetro que pode detetar a componente atencional prevista pelo modelo temporal. O segundo mensura a dimensão

atencional e afectiva a partir de indicadores fisiológicos, nomeadamente a atividade muscular facial e a variação da frequência cardíaca, e procura ver se estes indexam, quer a detecção da informação temporal quer os enviesamentos que sustentam o efeito em causa.

Capitulo I: Efeitos da Familiaridade em Julgamentos de Duração

Em nossas vidas diárias, somos frequentemente confrontados com experiências de distorção temporal subjetivas quando encontramos estímulos ou eventos que nos são familiares. Por exemplo, um anúncio pode parecer mais longo por o conhecermos previamente; a viagem de retorno a casa, percorrida numa rota familiar, parece levar mais tempo do que a experiência de voltar por uma via pouco familiar; a apresentação de um discurso político parecer que nunca mais acaba por ter os mesmos argumentos de sempre e palavras conhecidas parecerem ficar "suspensas no ar", durando mais tempo no meio de palavras desconhecidas faladas numa língua estrangeira. A familiaridade tem um efeito de dilatar a nossa experiência subjetiva da duração do tempo.

Um número considerável de estudos experimentais documentam este efeito de familiaridade, usando múltiplas abordagens para a operacionalização da familiaridade, Sistematicamente, tem sido relatado que a duração de estímulos mais familiares é percebida ser mais longa do que a de estímulos menos familiares, similarmente, quando a familiaridade é induzida experimentalmente por pré-exposição a esses estímulos em diferentes graus (e.g., Kleider & Goldinger, 2004; Masson & Caldwell, 1998; Ono & Kawahara, 2008; Paller et al. 1991; Witherspoon & Allan, 1985), ou quando os estímulos escolhidos variam previamente em familiaridade (e.g., Chastain & Ferraro, 1997; Reber, Zimmermann, & Wurtz, 2004; Reingold & Merikle, 1988; Rhodes & McCabe, 2009; Warm, et al., 1964).

O primeiro estudo a identificar o efeito de familiaridade na duração, faz uso da familiaridade pré-experimental, neste caso definida pela frequência de uso das palavras na língua (Warm, Greenberg, & Dube, 1964). Embora as palavras tenham sido apresentadas com uma duração real fixa (isto é, 1s), sua percepção foi sobrestimada para palavras familiares (i.e., mais frequentes na língua) em comparação com as menos familiares (i.e., menos frequentes na língua). Este padrão de resultados foi replicado várias vezes em estudos posteriores, com outras manipulações de familiaridade e sob uma grande diversidade de condições experimentais (e.g. (Chastain & Ferraro, 1997; Devane, 1974, Hochhaus, Swanson, & Carter, 1991, ver abaixo), apesar de existirem algumas evidências contrárias (e.g., Avant, Lyman & Antes, 1975, Ono et al., 2004, Schiffman & Bobko, 1977, Thomas & Weaver, 1975).

Esta literatura estabelece uma relação entre familiaridade e duração subjetiva num contexto de julgamentos prospectivos. Isto é, em condições nas quais os indivíduos sabem a priori que um julgamento de duração será necessário e, portanto, envolve o monitoramento contínuo e ativo do tempo desde o início até ao fim da apresentação do estímulo. Este tipo de julgamentos são distintos dos fenómenos de estimação do tempo retrospectivo, em que os indivíduos não têm consciência sobre a dimensão temporal do julgamento, a não ser apenas após o intervalo de apresentação do estímulo (ver Block & Zakay, 1997, Brown, 2010, Zakay & Block, 2004). Assim o efeito de familiaridade que estamos a abordar refere-se apenas e só a julgamentos prospectivos das durações. É sobre estes julgamentos que se verificam os efeitos de familiaridade.

Diversas características do processamento de estímulos familiares foram abordadas para explicar este fenómeno, dado que a familiaridade emerge das representações em memória de longo prazo do estímulo, e afeta diferentes características do seu processamento em múltiplas vias da cognição (Kahneman, 1973). Assim o efeito de familiaridade na duração subjetiva tem sido essencialmente associado a dois níveis de alterações no processamento de propriedades não-temporais do estímulo: a eficiência no processamento dessas informações, e a experiência metacognitiva de fluência que surge a partir desse processamento (i.e., quão fluente o processamento do estímulo é percebido ou experienciado). A primeira perspectiva sustenta-se em processos atencionais enquadrados em modelos dedicados de percepção temporal (e.g., Chastain & Ferraro, 1997; Hochhaus et al., 1991) e sua relação com uma distribuição de recursos cognitivos (Block, Hancock, & Zakay, 2010; Brown, 1997, 2008; Nobre & Coull, 2010; Zakay & Block, 1996, 1997). A segunda perspectiva (Kleider & Goldinger, 2004, Masson e Caldwell, 1998; Reber et al., 2004), enfatiza as teorias de atribuição geral de julgamento, baseadas em características experienciais tais com a fluência e sentimentos de familiaridade (Alter & Oppenheimer, 2008; Reber, Wurtz, & Zimmermann, 2004; Schwarz, 2004).

O efeito da familiaridade em julgamentos de duração

O *efeito de familiaridade* aqui abordado refere o fenómeno de expansão, prolongamento, ou sobrestimativa da duração de estímulos familiares em condições em que estamos a tender às características temporais dos estímulos.

Num estudo prototípico sobre este efeito de familiaridade, um conjunto de estímulos (e.g., palavras, faces ou formas) é apresentado (e.g., um estímulo por segundo) aos participantes no início da sessão experimental como uma tarefa de familiarização sem nenhum tipo de julgamento. Numa segunda fase da experiência, alguns dos estímulos são apresentados intercalados (entre ensaios) com novos estímulos (i.e., não apresentados anteriormente). Em cada ensaio, a duração do estímulo que varia entre os ensaios (por exemplo, 0,9, 1,0 e 1,1 s) é imediatamente julgada após o seu término (utilizando, por exemplo, uma escala de classificação ou o método de bissecção psicofísica, para uma descrição detalhada do paradigma ver Fernandes & Garcia-Marques, 2012, em anexo nesta tese). Os resultados normalmente mostram que os estímulos familiares (i.e., exposição anterior) têm maior probabilidade de serem julgados como mais longos do que os estímulos não familiares (isto é, estímulos não repetidos) (e.g., Masson & Caldwell, 1998; Kleider & Goldinger, 2004; Witherspoon & Allan, 1985).

O efeito de familiaridade foi detetado quando duração de estímulos previamente familiares foi r julgada mais longa do que estímulos não-familiares (e.g., Warm et al., 1964) mas já foi obtido em muitas outras condições experimentais. Originalmente associado à frequência de uso das palavras na língua (Chastain & Ferraro, 1997; Devane, 1974, Hochhaus et al., 1991; Warm et al., 1964), o efeito rapidamente foi demonstrado usando outros tipos de familiaridade pré-existente que encontraram efeitos semelhantes, como palavras versus não-palavras (e.g., Reber, Zimmermann, & Wurtz, 2004; Reingold & Merikle, 1988; Taylor & Lupker, 2006), conhecimentos prévios (e.g., Rhodes & McCabe, 2009; Kowal, 1976, 1987), ou associações semânticas (e.g., Marohn & Hochhaus, 1988, Ono & Kawahara, 2008).

O efeito é também encontrado com a familiaridade induzida experimentalmente por exposição anterior (Masson & Caldwell, 1998, Witherspoon & Allan, 1985).Por exemplo, Witherspoon e Allan (1985) induzem familiaridade por a codificação prévia de estímulos. Os seus participantes avaliaram a duração da exposição de palavras-alvo apresentadas brevemente (i.e., 30 a 50 ms) que foram lidas anteriormente numa tarefa de familiarização. Os julgamentos de duração foram mais longos para palavras previamente estudadas em comparação com novas palavras (não repetidas). Estes resultados foram replicados em estudos subsequentes que usaram delineamentos experimentais semelhantes (e.g., Kleider & Goldinger, 2004, Masson & Caldwell, 1998, Paller et al., 1991).

A generalidade do efeito de familiaridade é demonstrada pelo efeito ser verificado a diferentes níveis:

Tipo de estímulos e materiais experimentais. O efeito de familiaridade ocorre no domínio visual para faces (e.g., Fernandes & Garcia-Marques, 2016; Stoyanova & Bohdanecky, 1988), palavras (e.g., Warm & McCray, 1969), frases (e.g., Kowal, 1976), formas e figuras (Ono et al., 2007), ou imagens de objetos (e.g., Schiffman & Bobko, 1977), e no domínio auditivo para a música (Kowal, 1987). *Intervalos de tempo*. O efeito de familiaridade foi detetado em diferentes intervalos de duração, na ordem dos milissegundos (i.e., abaixo de 100 ms, Stoyanova & Bohdanecky, 1988), na ordem de centenas de milissegundos (i.e., menos de 1 s, Reber et al., 2004), na ordem de segundos de duração (Schiffman & Bobko, 1977), ou acima (i.e., minutos, Avni-Babad & Ritov, 2003).

Em diferentes contextos de julgamento. O efeito de familiaridade ocorre no contexto de condições de julgamento único (i.e., apenas estimativas de duração, Hochhaus et al., 1991) e em condições de julgamento múltiplo (i.e., avaliando outras características do estímulo, Kleider & Goldinger, 2004).

Paradigmas experimentais. O efeito de familairdade parece se generalizar para diferentes tarefas temporais, incluindo *rating-scales* (e.g., Masson & Caldwell, 1998), estimativas de magnitude (e.g., Stoyanova & Bohdanecky, 1988), com o método de bissecção (e.g., Fernandes & Garcia Marques, 2016a), ou o método de produção (e.g., Taylor & Lupker, 2006), e outros (e.g., Reingold & Merikle, 1988; Ono et al., 2004).

Globalmente, uma revisão da literatura dispersa sobre este efeito levanta a hipótese deste efeito da sobrestimação da familiaridade nos julgamentos de duração ser muito robusto. Contudo, a mesma literatura não é clara sobre quais as diversas contingências (i.e., os moderadores efetivos) deste efeito, que o permitem a identificação dos seus mecanismos subjacentes. Apenas sugere que estes poderão estar associados quer ao ganho na eficiência de processamento dos estímulos familiares quer ao ganho de uma experiencia subjetiva de fluência associado, que analisamos de seguida.

Familiaridade: Eficiência de processamento e experiência subjetiva de fluência

Os efeitos da familiaridade de um estímulo têm sido abordados tendo em conta dois atributos do processamento de estímulos familiares a eficiência com que são processados (Kahneman, 1973) e a experiencia subjetiva ativada nesse processamento (Reber, Winkielman, & Schwarz, 1998).). O denominador comum, ou princípio unificador destes

efeitos sugere ser a eficiência de processamento que liberta recursos atencionais e promove uma experiencia positiva de fluência.

A informação perceptiva (i.e., a clareza do percepto) ou conceptual (e.g., significado) de um estímulo (as suas características não temporais) familiar são mais facilmente processadas facilitando as decisões ou julgamentos temporais (ver Matthews & Meck, 2016). A familiaridade facilita a identificação de estímulos (e.g., palavras ou faces) quando apresentados muito brevemente (e.g., Jacoby & Dallas, 1981; Witherspoon & Allan, 1985) ou sob condições mais difíceis de extrair uma representação perceptiva, como "*backward masking*" (e.g., Feustel et al , 1983, Whittlesea, 1993), excentricidade visual (e.g., Martelli, Majaj & Pelli, 2005, Sassi et al., 2014) e movimento (e,g., Lander e Bruce, 2003; Matthews, Benjamin & Osborne, 2007). A familiaridade também facilita a categorização de faces (e.g., Bruce & Young, 1998) e palavras (e.g., Christie & Klein, 1995), torna mais rápidas as decisões corretas (e.g., Scarborough, Cortese & Scarborough, 1977; Taylor & Lupker, 2006), a velocidade da leitura ou latência para pronunciar palavras e frases (e.g., Kolers & Ostry, 1974; White, 2008). Além disso, os estímulos familiares são mais rapidamente detectados em tarefas de procura visual (e.g., Wang, Cavanagh & Green, 1994; Lubow e Kaplan, 1997), têm fixações de rastreamento ocular mais rápidas e menos número de fixações do que estímulos desconhecidos em paradigmas de "*eye tracking*" (e.g., Althoff & Cohen, 1999; Hsiao & Cottrell, 2008; White, 2008). Os estímulos repetidos estão também associados a uma eficiência da atividade e processamento neuronal (e.g., De Baene & Vogels, 2010; Grill-Spector, Heson, & Martin, 2006).

Em geral esta eficiência de processamento tem como consequência uma diminuição na utilização da capacidade de memória de trabalho (Jackson & Raymond, 2008), possibilitando mais recursos atencionais para outros processos cognitivos controlados e determinados por objetivos (Johnston et al., 1990; Parks & Hopfinger, 2008). Tal facto serviu de base à perspetiva dos modelos temporais que explicamo efeito de familiaridade nos julgamentos de duração que se contrapõe com a uma perspectiva assumida por modelos de julgamento que assumem a eficiência de processamento como originando uma experiencia subjetiva de fluência que pode enviesar os julgamentos temporais. A primeira perspetiva é enquadrada no campo da perceção temporal foca a dimensão de eficiência no processamento (Eagleman & Pariyadath, 2009; Grondin, 2010; Matthews & Meck, 2016).A segunda perspectiva é enquadrada no campo da cognição social por modelos de julgamento e foca a experiencia

subjetiva de fluência de processamento de estímulos familiares (Alter & Oppenheimer, 2008; Reber, et al., 2004; Schwarz, 2004).

A primeira perspectiva, é uma que pretende explicar os processo de percepção de tempo. Assim integra o efeito como mais um dos fenómenos de distorção ou ilusão temporal que são identificados no campo da percepção de tempo. São exemplos, os efeitos das emoções (i.e., estímulos emocionais aparentam durar mais tempo que estímulos neutros; Droit-Volet et al., 2004; Mella et al., 2010; Tipples, 2008), efeitos de preenchimento (i.e., Intervalos preenchidos aparentam durar mais tempo que intervalos vazios; Craig, 1973; Thomas & Brown, 1974; Wearden et al., 2007), o efeito de tamanho (i.e., objetos maiores aparentam durar mais tempo, Ono & Kawahara, 2007; Robertson & Gomez, 1980); Xuan et al., 2007), de contraste (i.e., estímulos mais fáceis de percepcionar são percebidos como mais longos, Bruno & Johnston, 2010; Stoyanova, Yakimoff & Mitrani, 1987; Terao et al., 2008), de sobrecarga cognitiva (i.e., menos ocupação da memória de trabalho durante o intervalo expande a sua duração subjetiva; Fortin & Breton, 1995; Fortin, Rousseau, Bourque, & Kirouac, 1993), de saliência (i.e., maior destaque de um estímulo numa série de estímulos maior a duração percebida; Pariyadath & Eagleman, 2007; Schindel, Rowlands, & Arnold, 2011; Tse et al., 2004), entre outros efeitos (ver *tabela 2* em Fernandes & Garcia-Marques, 2012, em anexo nesta tese). Notoriamente, a grande maioria destes efeitos ocorrem numa direção positiva de sobrestimativa temporal em função da clareza da representação da informação não-temporal.

A segunda perspectiva, integra o efeito numa abordagem ao estudo do julgamento, e lida com o efeito em conjunto com outros efeitos que a familiaridade exerce sobre várias variáveis dependentes. Assim, o efeito da familiaridade na percepção de tempo pode ser integrado na família de efeitos de familiaridade baseados na repetição prévia, como o "*efeito de verdade*" (i.e., julgar uma informação repetida como mais verdadeira; Bacon, 1979, Hasher et al., 1977), o "*efeito de mera-exposição*" (i.e., avaliar um estímulo repetido como mais positivo; Bornstein, 1989; Zajonc, 1968), ou o "*efeito da falsa fama*" (i.e., considerar uma pessoa vista anteriormente como mais famosa; Jacoby, Woloshyn & Kelley, 1989; Weisbuch & Mackie, 2009). Manifestamente, embora esses efeitos estejam relacionados a outros tipos de julgamentos (ou seja, informações não temporais), todos eles geralmente ocorrem numa direção positiva (ou seja, os estímulos mais familiares são julgados como mais longos, mais agradáveis, mais verdadeiros, mais famosos, e assim por diante).

Nas próximas seções, fazemos uma revisão destas duas perspectivas focando as explicações do efeito de familiaridade oferecidas pelos modelos de processamento de informação na percepção de tempo e pelos modelos de impacto da fluência de processamento no julgamento. Os primeiros enquadram o efeito de familiaridade em processos atencionais (integrados em modelos dedicados de percepção de tempo), e os segundos em processos atribucionais (integrados em modelos genéricos de julgamento).

Capitulo II: Explicações do Efeito de Familiaridade pelos Modelos de Processamento de Informação na Percepção de Tempo

O efeito da familiaridade tem sido explicado pelos modelos de processamento de informação temporal na assunção de que o processamento de características não-temporais do estímulo exerce um efeito de "*interferência atencional*" no processamento do tempo (e.g., Chastain & Ferraro, 1997; Hochhaus et al., 1991; Warm & McCray, 1969). Esta interferência ocorre afetando a distribuição de recursos atencionais e de processamento às características temporais do estímulo, i.e., afectando a monitorização do tempo que requer uma atenção seletiva e sustentada (e.g., Brown, 1997, 2008; Buhusi & Meck, 2009; Coull, Vidal, Nazarian, & Macar, 2004; Nobre & Coull, 2010). Assim o processamento de informação não temporal como que divide a atenção dos indivíduos no momento de processamento das suas características temporais. afectando a eficiência com que o nosso relógio interno acede à duração do estimulo.

O impacto da divisão da atenção nas estimativas temporais

O efeito de "*interferência atencional*" – outra designação para a hipótese de distribuição de recursos atencionais – tem uma forte base empírica, e consiste no encurtamento dos julgamentos de duração quando aspetos não relacionados com o tempo "*desviam*" a atenção do processo de "*cronometragem*" do tempo, que deve ser continua e ininterrupta (Brown, 1997, 2006, 2008; Thomas & Weaver 1975; Block & Zakay 1996; Fortin, 2003; Buhusi, & Meck, 2006).

O paradigma de tarefa-dupla ("*dual-task*") tem sido preferencialmente utilizado para testar este efeito (mas ver Brown, 2008; Block et al., 2010, para uma relação de diferentes tipos de manipulação de distribuição de recursos). Tipicamente os participantes atendem à passagem do tempo (para posterior julgamento de duração) e simultaneamente executam uma tarefa concorrente, que pode variar em grau de dificuldade (e.g., Brown, 1985; Brown & Merchant, 2007; Zakay, 1989), ou contrastada com uma condição de julgamento temporal simples – "*single-task*" (Brown, 2006; Brown & Merchant, 2007; Zakay, 1998). Zakay, Nitzan, and Glicksohn (1983), por exemplo, utilizaram uma tarefa verbal concorrente com três níveis de dificuldade - ler palavras (fácil), nomear objetos mostrados em imagens (intermediário) e fornecer associados de palavras de baixa frequência (difícil) - comparando o

desempenho de reprodução de duração também com uma tarefa temporal simples. As durações reproduzidas foram progressivamente mais longas à medida que a dificuldade diminuiu e foram as mais longas na condição de tarefa temporal simples.

Estes resultados têm sido replicados para muitos tipos de tarefas secundárias, que envolvem ambos os processos "*low-level*" (e.g., discriminação perceptiva, detecção de alvos, procura visual; Macar et al., 1994; Coull et al., 2004) e/ou processos "*high-level*" (e.g., aritmética mental, decisão-lexical, leitura, Brown & Merchant, 2007; Hicks et al., 1976, 1977; Zakay et al., 1983; Brown, 1985, 1995, 1997; Zakay, 1989; Champagne & Fortin 2008), embora uma comparação sistemática entre estes níveis não tenha até ao momento sido empreendida. Numa relevante meta-análise reportando 90 estudos prospectivos, Block et al., (2010) encontrou um sistemático encurtamento da duração subjetiva sob condições de sobrecarga cognitiva.

Estas observações subscrevem a dependência crítica dos recursos atencionais para a monitorização do fluxo temporal, sustentada na ideia central de capacidade limitada distribuída genericamente pelos diversos processos cognitivos, particularmente relacionados com a atenção e memória de trabalho (Kahneman, 1973; Schneider & Shiffrin, 1977).

Evidencias mais claras que atestam esta relação, vêm de estudos em que a "quantidade" de atenção alocada entre as fontes de informação (temporal e não-temporal) varia em função de instrução dada ao participante, (e.g., Casini & Macar, 1997; Coull, Vidal, Nazarian, & Macar, 2004; Macar, Grondin, & Casini, 1994; Grondin & Macar, 1992). Por exemplo, Macar et al. (1994) demonstraram que quando a atenção era diretamente controlada pelo participante (alocando a atenção 0%, 25%, 50%, 75% ou 100% a palavras ou à sua duração) (por exemplo, 25% a palavras e 75% a duração), duração subjetiva expandiu-se à medida que aumentava a "*quantidade*" de atenção ao tempo.

A diminuição da duração subjetiva (proporcional à distribuição de recursos atencionais) tem sido interpretada como uma perda (ou diminuição da detecção) de "*informação temporal*" e formalizada em modelos de processamento de informação da percepção de tempo (e.g., Creelman, 1962; Gibbon, Church, & Meck, 1984; Taatgen et al., 2007; Thomas & Weaver, 1975; Treisman, 1963; Zakay & Block, 1996).

Processamento do tempo (modelos de relógio-interno)

Não estando os humanos equipados com nenhum tipo de receptor sensorial que permita captar a informação temporal (e.g., Coull, Cheng & Meck, 2011) estes modelos assumem a existência de um mecanismo interno para medir o tempo, operando como se de um relógio (cronómetro) se tratasse (para discussão comparada com outros modelos ver Buhusi & Meck, 2005; Grondin, 2010; Ivry & Schlerf, 2008). Este relógio interno é postulado (e.g., Creelman, 1962; Gibbon, Church, & Meck, 1984; Taatgen et al., 2007; Thomas & Weaver, 1975; Treisman, 1963; Zakay & Block, 1996) ser um sistema central que regista a duração subjectiva dos eventos com base na acumulação de unidades temporais [1] ao longo do tempo, assinalados por algum tipo de marcador (i.e., início e término do intervalo. Os modelos mais prevalecentes (SET: Gibbon, et al., 1984; Buhusi & Meck, 2006; AGM: Zakay & Block, 1996), assumem a existência de um mecanismo para medir o tempo, operando em 3 fases: "*clock*", "*memory*", e "*decision*" (see Figure 1A). É postulado que a fase de relógio interno tem três componentes centrais[2]: (1) um processador temporal ('*pacemaker*'); (2) um interruptor[3] ('*switch*'); (3) um acumulador. O processador temporal opera como um gerador que emite pulsos continuamente a uma determinada frequência, enviando-os para o acumulador através do interruptor. No início do estímulo a ser cronometrado, o interruptor (com uma latência variável) é accionado (fechando-se), permitindo que os pulsos sejam transferidos para o acumulador (memória de trabalho) durante o intervalo, até ao seu término, quando o interruptor volta a abrir. Deste modo, o número de pulsos registados no acumulador constituirá a representação da duração percebida: quanto maior o número de pulsos, maior a duração percebida.

Estes modelos de relógio interno permitem fazer predições sobre as distorções e ilusões temporais que surgem como resultado de interferências em algum dos vários componentes do relógio, e essa razão, torna estes modelos com um valor predictivo, por exemplo, integrando os processos de interferência atencional revistos acima, algo sem paralelo com outras propostas (ver Grondin, 2010; Matthews & Meck, 2016), como os modelos de eficiência de codificação neuronal (Eagleman & Pariyadath, 2009; Eagleman, 2008; Pariyadath & Eagleman, 2007; Sadeghi, Pariyadath, Apte, Eagleman & Cook, 2011),

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[1] Unidades hipotéticas que consistem em unidades mínimas informacionais de tempo, sejam conceptualizadas como meramente cognitivas ou de cariz biológico (ou neural).

[2] Os modelos mais recentes dos quais se incluem o SET e o AGM compreendem 3 fases de processamento das quais a do relógio interno é

[2] Os modelos mais recentes dos quais se incluem o SET e o AGM compreendem 3 fases de processamento das quais a do relógio interno é
uma delas (a primeira) e a única aqui discutida. Vários efeitos nos julgamentos de duração podem resultar em função de interferências nestas fases de processamento da informação temporal.

[3] Em alguns modelos como o AGM (Attentional Gate Model) este interruptor integra ainda outro componente, um portão ('gate'), que controla o foco e recursos atencionais dedicados ao processamento explícito do tempo. Para uma discussão sobre estas diferenças ver Lejeune (1998) e Zakay (2000).

teoria unificada de magnitude (ATOM, "Theory of Magnitude"; Walsh, 2003)., modelos de aprendizagem comportamental (LeT, "Learning-to-Time"; Machado, 1997), entre outros (ver também Fernandes & Garcia-Marques, 2012, em anexo nesta tese).

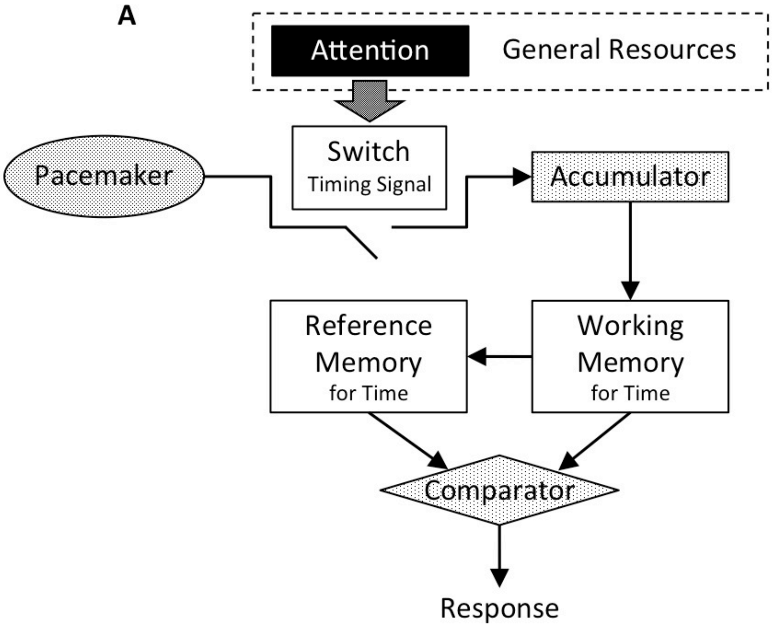

Figure 1A. The architecture of a generic pacemaker-accumulator model of time perception (following Gibbon et al., 1984). A dedicated pacemaker emits time pulses at a specific frequency; the pulses flow into the accumulator when the switch closes, remaining in that state until the end of the interval when it opens again. Attention controls the operation of the switch – the selective and sustained attention to time. The accumulated pulses during a specific interval results in the representation of subjective duration, which may be transferred to working memory and subsequently to long-term memory. The duration judgment (or temporal decision in general) is relative as the product of a comparison between the working memory representation – the current duration – and previous stored representations of duration (i.e., the reference memory). Partially adapted from "Interval Timing With Gaps and Distracters: Evaluation of the Ambiguity, Switch, and Time-Sharing Hypotheses," by C. V. Buhusi and W. H. Meck, 2006, *Journal of Experimental Psychology: Animal Behavior Processes, 32*, p. 330. Copyright 2006 by the American Psychological Association.

É proposto a atenção controlar a ação do interruptor e o fluxo de pulsos para o acumulador (mas ver Zakay & Block, 1996), e se esta é desviada (ou utilizada para outros

processos cognitivos, como numa tarefa concorrente) durante o intervalo, a informação temporal é perdida – os pulsos não são detectados – consequentemente, quanto menor a representação temporal será (e.g., Buhusi & Meck, 2009; Lejeune, 1998; Meck, 1984; Zakay, 1989; Zakay & Block, 1996). Por outras palavras, se recursos atencionais são divididos ao longo do tempo de um estímulo, o interruptor alterna entre um estado aberto e um fechado (Lui, Penney, & Schirmer, 2011, Penney, Allan, Meck , & Gibbon, 1998). Modelos mais recentes prevêm que a divisão de recursos atencionais, afeta a contagem de pulsos, nas fases do acumulador e da memória de trabalho para a duração (e.g., Buhusi & Meck, 2006, 2009), uma vez que a acumulação de pulsos requer manter atualizada uma representação do tempo transcorrido (desde o inicio do intervalo) a cada momento, o que ocupa a memória de trabalho (*ver Figura 1A*); ao ocupar a memória de trabalho, uma espécie de fuga ("leak") pode ocorrer, tendo como consequência um decréscimo da duração percebida (para uma demonstração ver Buhusi & Meck, 2006, 2009).

Recursos atencionais e o efeito de familiaridade

O facto de a familiaridade possibilitar uma maior disponibilidade de recursos atencionais tem sido interpretada como um mecanismo através do qual os julgamentos de duração são sobrestimados (e.g., Chastain & Ferraro, 1997; Hochhaus et al., 1991; Warm & McCray, 1969; Avni-Babad & Ritov 2003; Rhodes & McCabe 2009; Stoyanova & Bohdanecky, 1988). Segundo os modelos de relógio interno, o processamento de estímulos familiares (em comparação com os não-familiares) interfere menos no "*switch*", levando a uma detecção temporal crescente e, consequentemente, a uma maior acumulação de unidades de tempo, representando uma duração subjetiva mais longa.

O teste de um modelo que assume mecanismos de atenção para explicar os efeitos de familiaridade deve ser aquele que usa, por exemplo, o paradigma de "*dual-task*" descrito acima, que contrasta o desempenho na tarefa temporal com e sem tarefa concorrente. No entanto, para nosso conhecimento, apenas uma experiência contrasta tarefas temporais e concorrentes ortogonalmente com a familiaridade (Chastian & Ferraro, 1997). Chastian e Ferraro (1997, experiência 6) pediram aos sujeitos que utilizando uma escala (1 = curto, 4 = longo) estimassem a duração de palavras familiares (i.e., alta frequência na língua) e palavras não-familiares (i.e., baixa frequência na língua) apresentadas durante 83 e 167 ms. Concorrentemente, os participantes tinham que manter em memória de trabalho conjuntos de letras (i.e., 1, 2 ou 3 letras) apresentadas no início do ensaio e fazer um julgamento de

memória depois da tarefa temporal. Foi verificada uma interação entre sobrecarga cognitiva e familiaridade, sendo o efeito da familiaridade apenas significativo nas palavras de baixa frequência. Este efeito seria de esperar pois uma condição de familiaridade tem maior probabilidade de resistir a interferências (e.g., Paap & Noel, 1991; Regan, 1981).

Por outro lado, os modelos de relógio interno prevêem que as variações na atenção terão impacto não apenas nos enviesamentos ("bias") nos julgamento de duração mas também na sensibilidade à duração (, Brown, 2008; Creelman, 1962; Grondin, 2010). O "bias" e a sensibilidade (e sua relação funcional) são incorporados nos modelos de relógio interno, numa perspetiva psicofísica, e indexados, respetivamente, pelo julgamento da duração e sua variabilidade (e.g., Gibbon et al., 1984; Killeen, Fetterman & Bizo, 1997). Argumenta-se que as latências de abertura e fecho do "*switch*", que marca o intervalo a ser julgado, são causadas por alguma variância na percepção temporal. Esses erros de marcação causados por variações no monitoramento da atenção explicam os efeitos na estrutura temporal do intervalo e consequentemente, nas alterações na sensibilidade (ver Grondin, 2010). De facto, observou-se uma diminuição da sensibilidade temporal em condições de sobrecarga atencional, tais como as criadas por manipulações de tarefas duplas (por exemplo, Brown, 1997, Macar, 1994). A meta-análise de Block et al., (2010), agrupando 45 estudos, sugere também uma queda significativa na sensibilidade induzida pela menor capacidade atencional. Essas premissas também têm como correlato a expectativa de que o impacto da familiaridade em ambos os índices se relacionará negativamente.

Do nosso conhecimento, apenas Witherspoon e Allan (1985, exp.1) exploraram os efeitos de sensibilidade da familiaridade, pedindo aos participantes que fizessem simultaneamente com julgamento da duração, identificassem as palavras apresentadas muito brevemente (i.e., 30 a 50 ms). A familiaridade promoveu um efeito na sensibilidade temporal, mas somente quando as palavras foram incorretamente identificadas. Contudo, a tarefa de identificação explícita pode ter tornado o estímulo mais saliente, num contexto de difícil discriminação temporal (i.e., durações muito curtas), e essa ser a razão da sensibilidade temporal ser dependente do reconhecimento (ver Kleider & Goldinger, 2004)

Embora os estudos de Chastian e Ferraro (1997, exp. 6) com manipulação de capacidade e de Witherspoon e Allan (1985, exp.1) com medidas de sensibilidade, sejam favoráveis ao envolvimento de processos atencionais, dúvidas existem quando aos efeitos da familiaridade em condições implícitas, sem processamento explícito de informação não-temporal, particularmente referente ao próprio estímulo.

No entanto, o efeito de familiaridade é encontrado quer quando é solicitado aos participantes para ativamente as ambas as características temporais e não-temporais dos estímulos, quer quando julgamentos concorrentes não necessários (e.g., Chastain & Ferraro, 1997; Hochhaus et al., 1991; Reber et al., 2004). Para um exemplo, Witherspoon e Allan (1985) mostraram que episódios de codificação anteriores induzidos experimentalmente (repetição) poderiam expandir julgamentos de duração subsequentes, de forma comparável, em condições de "*dual-task*" (experiência 1, identificação de palavras) ou de somente julgamento de duração (experiência 2).

Mas como esse efeito implícito pode ser explicado pela hipótese de alocação de atenção? A atenção ao tempo é um processo controlado e é seletivo ao fluxo contínuo da entrada sensorial de outras modalidades (ou seja, características não-temporais do estímulo). Dois tipos de influência sobre a atenção seletiva são usualmente distinguidos, uma influência automática exógena, e um processo controlado, ou influência endógena (Posner, Snyder, & Davidson, 1980; Shiffrin & Schneider, 1977). O início súbito do estímulo a ser "*cronometrado*" irá conduzir a atenção exógena às suas propriedades físicas, particularmente características visuais ou auditivas (e.g., Theeuwes, 1994). O processo implícito de características não-temporais é impulsionado por processos perceptivos automáticos imperativos e rápidos (Deacon & Shelley-Tremblay, 2000; Palermo & Rhodes, 2007). As experiências que utilizam paradigmas de interferência fornecem evidências que corroboram o processamento de automatismo, por exemplo, das palavras - até ao acesso do seu significado (para uma revisão, ver MacLeod, 1991) ou o processamento holístico na percepção das faces humanas - até à sua identificação (para uma revisão ver Bruce & Young , 1998), sugerindo que a supressão é difícil ou mesmo impossível em algumas condições (por exemplo, Neely & Kahan, 2001). Então é francamente plausível o envolvimento de processos atencionais em condições implícitas em tarefas temporais, principalmente porque a monitorização do tempo é muito sensível a qualquer interferência (para uma discussão ver Brown, 2008). Contudo, faltam evidências experimentais que sustentem esta hipótese no contexto de julgamentos de duração cujos estímulos que preenchem o intervalo de tempo variem em familiaridade.

Monitorização do tempo e efeito de familiaridade: efeitos iniciais e tardios da atenção seletiva

Paradigmas utilizando pistas espaciais ou temporais demonstram que efeitos da detecção inicial do estímulo (que marca o intervalo) são críticos na estimação da sua duração

(Enns, Brehaut, & Shore, 1999; Mattes & Ulrich, 1998; Seifried & Ulrich, 2011). A atenção às propriedades não-temporais do estímulo será necessária para o início da contagem de pulsos do relógio interno (e.g., Lejeune, 1998). Este tipo de processo, associado à latência do "*switch" (ver Figura 1B)*, sugere promover um efeito de enviesamento constante independente da duração do estímulo e é designado na literatura por efeito de "*intercept*" (see Mathews & Meck, 2016; Killeen et al., 1997; Eisler, 1979). E a familiaridade tem sido mostrada afectar a "*atenção exógena*" (Posner, Snyder, & Davidson, 1980) de forma que o que é familiar é rapidamente detectado, como revelado por paradigmas de distribuição da atenção (e.g., Montani, Facoetti, & Zorzi, 2014), ou de "*eye-tracking*" (Althoff & Cohen, 1999; Hsiao & Cottrell, 2008; White, 2008). O impacto inicial

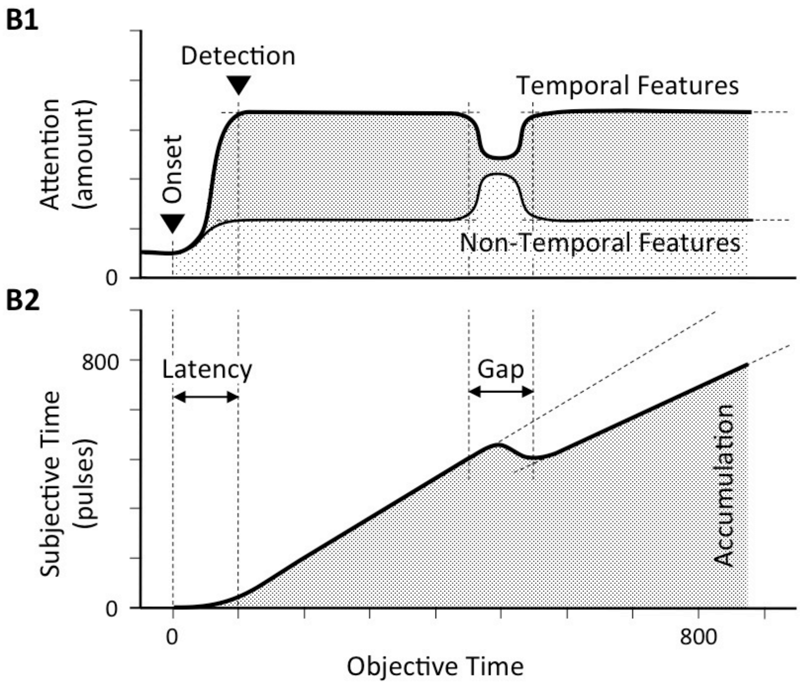

Figure 1B. The predicted effects of attention in subjective time accordingly to switch-accumulation account (following Lejeune, 1999; Buhusi & Meck, 2006); the attention resources as a function of temporal and non-temporal features (panel B1), the accumulation of pulses (i.e., subjective time) as a function of objective time (panel B2). At the sudden onset of the stimulus to be timed, attention is rapidly and involuntarily oriented toward it (i.e., exogenous attention). The detection of the low-level perceptual features of the stimulus takes a certain amount of time (i.e., latency), which marks the closing of the switch; attention is consciously directed to temporal features, and begins the accumulation process of the pulses

emitted by the pacemaker. The sustain attention towards time keeps the constant accumulation of temporal units (i.e., pulses). In parallel, some of attentional resources are involuntary devoted to non-temporal features (irrelevant to the timing task). The controlled process of attention is selective to time, but could be interfered by salient non-temporal aspects of the stimulus (as late high-level conceptual processes). If attention is (in)voluntarily redirected to these aspects, creates a gap in the selection of temporal features – the switch opens; the accumulation of pulses is interrupted until the re-initiation of the selective process, and the correspondent re-closing of the switch. The latency of closings and the frequency of openings of the switch will lead to lesser pulses accumulated and a shortening of subjective time.

O impacto inicial da familiaridade também é documentado por investigações de "*Event Related Potentials*" (ERP) mostrando que os estímulos familiares têm impacto no processamento em fases muito iniciais (50-200ms) (e.g., Hanso, Bachmann & Murd, 2010; Shtyrov & Lenzen, 2016). Por exemplo, Shtirov et al. (2013) encontraram uma diferenciação do padrão ERP a 100ms entre palavras e não palavras (i.e., não-familiares) apresentadas no campo visual periférico. Assim, é provável que estímulos familiares promovam efeitos semelhantes de outras manipulações de atenção, afectem a contagem inicial do relógio interno e promovem um enviesamento constante independe da duração – um efeito de "*intercept*". Como a familiaridade torna mais rápida e eficiente a detecção precoce do estímulo (reduzindo a variabilidade com que o "*switch*" será acionada), mais pulsos serão acumulados e o tempo será sobrestimado.

Mas o tempo também depende dos mecanismos de atenção sustentada (*ver Figura 1B*). A atenção exógena é de ação rápida, enquanto a atenção endógena é um pouco mais lenta - agindo com latências de cerca de 100-150 ms (Theeuwes, Atchley, & Kramer, 2000). Após a orientação da atenção, os processos cognitivos são necessários para desviar a atenção de um estímulo (Wager, Jonides, & Reading, 2004) ou para sustentar a atenção nela (Sarter, Givens & Bruno, 2001). Para sustentar a monitorização do tempo, o sistema precisa manter a atenção através de toda a duração do estímulo. Este monitoramento é muito sensível a qualquer desvio de atenção (Brown, 2008). A evidência mostrou que as mudanças na atenção durante a duração da apresentação dos estímulos interferem com os julgamentos de duração. Promovendo lacunas na monitoração do tempo (por exemplo, apresentando um distractor no meio da apresentação de estímulos) supostamente levando ao fechamento e abertura do interruptor do relógio (ver Buhusi & Meck, 2009; Zakay & Brown, 1997), promovendo

subestimativas que dependem da duração dos estímulos em si (efeito de "slope", ver Matthews & Meck, 2016). Adicionalmente, os processos cognitivos subjacentes à atenção sustentada são necessariamente recrutados mais intensamente à medida que decorre um intervalo temporal (Coull, 1998). Assim durações mais longas são suscetíveis de ter lacunas na monitorização, no entanto, isso será menos prejudicial para estímulos familiares. Sendo assim, os efeitos da duração da familiaridade provavelmente serão moderados pela duração dos estímulos.

A familiaridade também é mostrada afetar os processos posteriores de atenção, criando diferenças no processamento de estímulos repetidos e não repetidos detetados na atividade de ERP a 300-400 ms (Friederici, 2002; Hagoort, 2008). Isto sugere que a familiaridade também é suscetível de interferir com o mecanismo de atenção associado com o processamento "*high-level*" relacionado a estruturas de conhecimento conceptual. Neste intervalo de tempo mais elevado, devemos esperar que ocorram mais "*gaps*" no monitoramento do tempo, e assim provável que o efeito de familiaridade também seja dependente da duração do estímulo, particularmente se envolver estímulos com uma componente conceptual.

Apesar da quase totalidade dos estudos sobre o impacto da familiaridade utilizar múltiplas durações objetivas nos seus desenhos experimentais, não é feita menção a este efeito, embora sejam reportados por vezes interações significativas entre familiaridade e duração (e.g., Kowal, 1976; Stoyanova & Bohdanecky, 1988; Reingold & Merikle, 1988), que vão no sentido de efeitos de "*slope*". Uma exploração cuidada da relação dinâmica entre as fases de processamento dos estímulos (i.e., familiares e não-familiares) ao longo do tempo é altamente informativo do modo como pode afetar as estimativas de duração dependentes da familiaridade dos estímulos.

Capitulo III: Explicações do Efeito de familiaridade pelos Modelos de Fluência de Processamento

Os diversos efeitos da familiaridade detetados nos julgamentos têm sido explicado na assunção de que a familiaridade promove uma experiencia subjetiva (sentimento) de facilidade no processamento (fluência) de características não-temporais do estímulo (percetivas ou conceptuais). Embora na literatura de decisão e julgamento tenham sido assumidos que os sentimentos possam suportar diretamente essas decisões e julgamentos (por exemplo, Kahneman & Tversky, 1973, Schachter & Singer, 1962; Schwartz, 2004), esta explicação tem ficado fora do escopo geral do campo de percepção temporal. No entanto encontramos alguns conjuntos de estudos que diretamente assumem que os julgamentos de duração, também eles, ancoram na experiência subjetiva de facilidade - ou *fluência de processamento* - associada à exposição prévia (i.e., repetição) (e.g., Kleider & Goldinger, 2004; Reber et al., 2004; Witherspoon & Allan, 1985). Desta forma definem os julgamentos de tempo como sendo sustentados por processos de julgamentos em outras dimensões não-temporais.

As abordagens sobre fluência, enquadram os julgamentos como sendo baseados nas características de processamento tanto das componentes conceptuais como percetivas da informação processada: focam as características relacionadas com a "*qualidade de processamento*" dessa informação – a experiência de fluência desse processamento (Whittlesea & Leboe, 2003). A fluência de processamento – associada à exposição prévia (i.e., repetição), é amplamente assumida como podendo ser usada como uma pista metacognitiva em julgamentos numa ampla gama de domínios (para uma revisão, ver Reber, et al., 2004; Schwarz, 2004).

O facto da experiência de familiaridade /fluência ser um sentimento difuso e positivo (Garcia-Marques, 1999) torna-a suscetível de atribuições erróneas. Isso leva à possibilidade de que mesmo quando a fluência não é um resultado direto de uma operação cognitiva que objetivamente contribui para esse julgamento, ela pode ser atribuída à dimensão avaliada (i.e., hipótese de atribuição de fluência, Jacoby & Dallas, 1981; ver Oppenheimer, 2008). Por exemplo, é provável que os estímulos fluentes (baseados na exposição prévia) sejam mais agradáveis (Bornstein & D'Agostino, 1992, Zajonc, 1998), mais claros (Jacoby et al., 1988, Whittlesea, Jacoby & Girard, 1990), mais famosos (Jacoby, Kelley, Brown, & Jasechko, 1989) e mais compreensíveis (Carroll & Masson, 1992) do que os estímulos menos fluentes.

Se assumimos a duração como um julgamento com fatores comuns com outros julgamentos, é plausível que a fluência de processamento influencie julgamentos de duração de forma semelhante (como afirmado por Jacoby e Dallas, 1981). Jacoby e Dallas (1981) notaram que os participantes espontaneamente relataram que algumas palavras apresentadas anteriormente pareciam "*jump-out*" do monitor, dando a impressão de uma duração mais longa (no contexto da identificação perceptual supraliminar). Essa clareza perceptiva baseado na memória – *fluência perceptual relativa* – foi sugerido ser atribuída erroneamente à duração. Witherspoon e Allan (1985) e outros investigadores seguiram essa hipótese (e.g., Kleider & Goldinger, 2004, Paller et al., 1991). Em geral, estes estudos mostraram que estímulos repetidos (a partir de uma tarefa de codificação anterior) eram mais fáceis de reconhecer (isto é, a fluência objetiva) e também percebidos mais tempo do que novos estímulos (não repetidos). Esses dados sugerem que a fluência perceptiva relativa induziu sentimentos de familiaridade que foram atribuídos a julgamentos de duração. Como a experiência de fluência é gerada automaticamente (e.g., Jacoby & Witherspoon, 1982), a necessidade de identificação perceptiva ou de reconhecimento (de informações não temporais) não é necessária para que o efeito temporal ocorra (e.g., Paller et al., 1991; Reber et al., 2004; Witherspoon & Allan, 1985, experiment 2).

Processos ativos no impacto da familiaridade/fluência nos julgamentos

A *Figura 2* descreve em termos genéricos, um conjunto de pressupostos de abordagens diferentes sobre fluência para no processo de falsa-atribuição e condições que podem modular a sua ocorrência. Assumindo que o efeito da familiaridade em julgamentos de duração esteja relacionado com efeitos de fluência, há características específicas que devemos esperar para caracterizar ou modular o efeito de familiaridade. Estas associam-se à definição do sentimento de familiaridade/fluência experienciado e ao modo como ele pode ser atribuído ao processamento das características temporais do estímulo.

<u>Sentimento de familiaridade/fluência e a hipótese de discrepância</u>

O sentimento experimentado ao processar um estimulo familiar/ fluência é um sentimento afetivo com valência positiva (Garcia-Marques & Mackie, 2000; Winkielman & Cacioppo, 2001) . Tal facto tem sido demonstrado tanto com julgamentos directos de familiaridade e ou afeto (Garcia-Marques, T. Mackie, Claypool, & Garcia-Marques, L. 2004 ;

Garcia-Marques, Prada, & Mackie, 2016) como a intervenção em processos de interferência de julgamentos e percepção (Garcia-Marques, T., Mackie,, Claypool, & Garcia-Marques, L., 2010) e com medidas fisiológicas diversas. A atividade muscular facial espontânea, avaliada com EMG facial, é um indicador genuíno de reações afetivas (e.g. Cacioppo, Petty, Losch & Kim, 1986, Dimberg, Thunberg, Elmehed, 2000). O zigomáticus major, o músculo responsável pelo sorriso, é indicativo de afeto positivo (e.g., Cacioppo et al., 1986; Dimberg et al, 2000), e tem se mostrado associado à fluência de processamento (por exemplo, Harmon-Jones & Allen, 2001; Topolinski, Likowski, Weyers e Strack, 2009; Winkielman & Cacioppo, 2001). Para um exemplo, Harmon-Jones e Allen (2001) descobriram que a elevada fluência perceptiva - ou facilidade de processamento - associada a faces femininas apresentadas anteriormente resultou em uma ativação automática do músculo zigomático e classificações mais positivas (Harmon-Jones & Allen, 2001; ver também Topolinski, Erle, & Reber, 2015, Topolinski, et al., 2009, Winkielman & Cacioppo, 2001).

A literatura sugere que a experiência subjetiva da fluência é dependente do contexto, que deriva de uma discrepância, e assim é uma fluência de processamento relativa. Esta abordagem de discrepância (Whittlesea & Williams, 1998; ver também Whittlesea & Williams, 2001; Whittlesea & Leboe, 2003; Wänke & Hansen, 2015) sugere que a experiência de fluência ou um sentimento de familiaridade decorre da discrepância entre o nível de fluência com que se espera que um estímulo seja processado e o nível real de fluência experimentado. É essa discrepância que desencadeia um processo de atribuição.

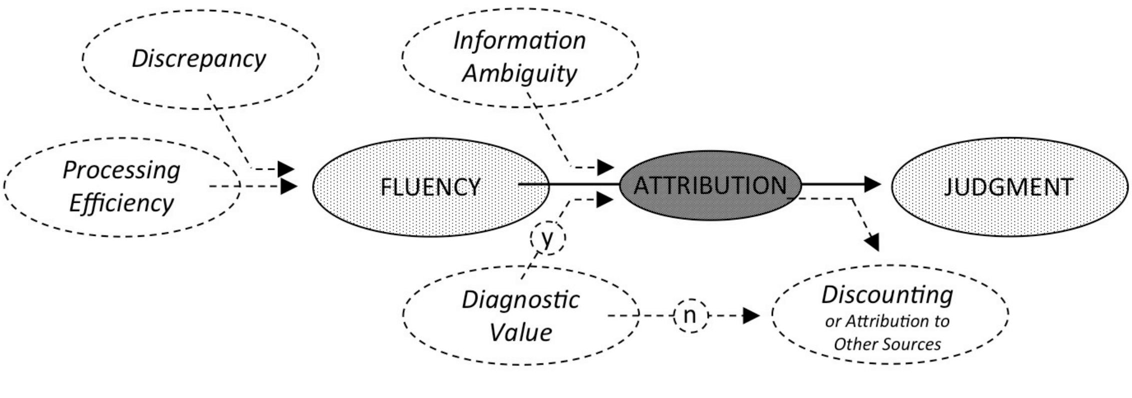

Figure 2. A generic comprehensive fluency-attribution framework (modeled after Jacoby and Dallas, 1981). The metacognitive fluency experience – related with the efficiency of ongoing perceptual or conceptual cognitive processes – is used as information (or a cue) toward judgment, which is mediated by attributional processes. The fluency experience depends of its discrepancy from the context – the relative fluency –, and is more likely to be attributed when

central information to the judgment at hand is ambiguous, more difficult to access or discriminate. Attribution is also more likely to occur if the experienced fluency has some diagnostic value to inform that judgment. The diagnostic value of fluency is lost, and fluency "discounted", when its real source could be identified, decreasing its impact on judgment. The central processes (i.e., fluency, attribution and judgment) are the core of the model, partially adapted from "The Secret Life of Fluency," by D. M. Oppenheimer, 2008, Trends in Cognitive Sciences, 12, p. 240. Copyright 2008 by Elsevier.

A primeira evidência de discrepância entre fluência esperada e real (em vez de nível absoluto) foi encontrada por Whittlesea e Williams (1998) no contexto de julgamentos de memória de reconhecimento. Os participantes foram convidados a ler e realizar um teste de reconhecimento de uma lista de palavras familiares (e.g., *bottle*), não-palavras regulares (e.g., *hension* - fácil de pronunciar) e não-palavras irregulares (e.g., *stofwus* – difícil de pronunciar), metade estudadas anteriormente (i.e., repetidas) e metade novas (i.e., não repetidas). Os autores descobriram que as não-palavras regulares provocavam a maior proporção de falsos alarmes (isto é, indevidamente reconhecida como lida anteriormente), seguida por palavras normais e, em seguida, por não-palavras irregulares, um padrão que não reflete a fluência de processamento objetivo esperada. Aparentemente, as não-palavras regulares (visualmente disfluentes) eram surpreendentemente mais fluentes do que os participantes esperavam (soando como palavras reais quando lidas em voz alta, por exemplo, *phrawg*, soa como *frog*), consequentemente, eles atribuíram essa fluência inesperada à familiaridade com a não-palavra, – em contraste, tanto a fluência sentida com palavras e a falta de fluência sentida com não-palavras irregulares poderia ser esperado pelos participantes, e, portanto, corrigida. Aparentemente foi a discrepância associada a essas expectativas que modularam a intensidade do sentimento de fluência.

No contexto de julgamento de duração , Reber et al. (2004, experimento 5) reproduziram parcialmente essa experiência (por exemplo, as palavras e as não-palavras não foram lidas em voz alta e os julgamentos de reconhecimento não foram exigidos) com duração como medida dependente. Os participantes fizeram julgamentos de duração de palavras, irregularidades regulares e irregulares apresentadas por 32, 48, 64 e 80 ms. Os resultados foram contudo inconsistentes com o estudo de Whittlesea e Williams (1998): as palavras foram percebidas durar mais tempo do que as não-palavras regulares, e estas, mais tempo do que as não-palavras irregulares.

Uma razão pela qual esta replicação pode ter falhado é que nem sempre está claro qual é o referencial ao qual nossa experiência de fluência é relativa. Whittlesea e Williams (1998) sugerem que expectativas anteriores estabelecem um padrão de comparação, mas essas expectativas podem emergir a partir de referências internas ou referências externas como as estabelecidas por contexto de referência (e.g., Hansen, Dechêne & Wänke, 2008; Hansen & Wänke , 2015; Laham, Alter, & Goodwin, 2009).

Dechêne, Stahl, Hansen e Wänke (2009) mostram como estas referências contextuais modulam o "*efeito de verdade*" (ou seja, itens repetidos são percebidos como mais verdadeiros) que só são observados quando itens repetidos são apresentados intercalados com novos, gerando uma experiência de fluência corrente dependente da discrepância de fluência dos estímulos apresentados anteriormente. Efeitos semelhantes ocorrem quando a duração é a medida dependente, evidenciado em dois conjuntos de estudos. Primeiro, os efeitos da familiaridade nos julgamentos de duração mostraram-se inexistentes quando a familiaridade é manipulada entre sujeitos (Kowal, 1976, Schiffman & Bobko, 1977). E segundo, como Gomez e Robertson (1979, experimento 1) mostram, que o mesmo ocorre com uma manipulação da fluência perceptiva. Estímulos maiores, que são mais fáceis de processar (i.e., elevada fluência perceptiva), são percebidos durar mais tempo do que os pequenos (i.e., baixa fluência perceptiva), mas somente quando ambos os estímulos foram apresentados na mesma sessão experimental; não foram encontradas diferenças no julgamento de duração em contexto homogéneo (i.e., manipulação entre-sujeitos). Assim, uma característica da discrepância é que o contexto de apresentação dos estímulos entre os ensaios, por exemplo, a ordem, número ou proproção (i.e., o contexto temporal) modula a experiência de fluência, supostamente porque modula a saliência e a expectativa de um estímulo a ser comparado com o outro (e.g., DAgostino, 1992, Hansen & Wänke, 2008, Jacoby et al., 1989, Whittlesea & Williams, 1998, Willems & Van der Linden, 2006). Conforme afirmado por Whittlesea e Leboe (2003), a variabilidade da fluência tornará as comparações mais prováveis de ocorrer e usadas para informar o julgamento. Assim, de uma perspectiva teórica e evidência empírica, todo o tipo de distribuição de estímulos entre os ensaios terão impacto na discrepância de fluência, algo que é comum ocorrer transversalmente aos estudos de perceção de tempo, mas carece de evidência experimental, particularmente, para os efeitos da familiaridade.

Um ponto de observação a relevar é que o contexto poderia determinar a intensidade da experiência de fluência e, portanto, ser indistinguível de um simples efeito de contraste, destacado na literatura de perceção temporal (ver Grondin, 2010; Matthews & Meck, 2016).

Entretanto, várias revisões deixam claro que o contexto determina o valor diagnóstico da experiência de fluência e essa experiência subjetiva nem sempre é consistente com a fluência objetiva determinada por um contraste simples (ver Wänke & Hansen, 2015; Whittlesea & Leboe, 2003). Embora os constructos tanto de "intensidade" como de "valor diagnóstico" possam não ser independentes, como discutido acima, demonstrações de correção ("*discounting*") de fluência e violações de expectativas de fluência (i.e., discrepância de fluência), se mantém contra um efeito simples de intensidade subjetiva como explicação de efeitos fluência em vários domínios de julgamento (e.g., D'Agostino, 1992; Hansen & Wänke, 2008; Jacoby et al., 1989, Whittlesea & Williams, 1998; Willems & Van der Linden, 2006), dos quais não podemos excluir a duração subjetiva.

Processo de atribuição da fluência à duração

A fluência experienciada pode então ser atribuída à duração. Mas para tal processo ocorrer devemos pressupor que o individuo percebe este sentimento como diagnóstico do tempo, que a situação é ambígua o suficiente para o poder atribuir erroneamente à duração quando dela não provêm e que nada no contexto o alerta para o erro que está a cometer.

Validade Ecológica da Fluência. Para este a fluência relativa deve ter algum valor diagnóstico (*ver Figura 2*). O uso da fluência como base para o julgamento provavelmente não é arbitrário. Os indivíduos tendem a atribuir uma fluência baseada na familiaridade a uma fonte apropriada como informação diagnóstica (Oppenheimer, 2008; Schwartz, 2004; Whittlesea & Williams, 2000). Sugere-se que os indivíduos aprendam a associar fluência a resultados específicos e implementem o significado inferido em contextos similares futuros – "*naïve theories"* (Schwartz, 2004; Schwarz & Clore, 2007). No contexto de julgamentos de reconhecimento, tanto a familiaridade (i.e., sentimento) como a memória (i.e., detalhes de informação sobre estímulo prévio) são sinais de memória emparelhados (Mandler, 1980; Yonelinas, 2001, 2002). Portanto, a fluência baseada na familiaridade é fortemente usada como uma heurística de reconhecimento, porque é uma pista ecologicamente válida para a memória (e.g., Begg et al., 1989; Jacoby & Dallas, 1981; Whittlesea et al., 1990). O mesmo racional pode ser pensado para os julgamentos de duração, porque os estímulos que são expostos anteriormente por um período de tempo mais longo são percebidos como sendo mais fluentes (e.g., Reber et al., 1998; Winkielman & Cacioppo, 2001; Foster, Gerger & Leder , 2015, Forster et al., 2016). Assim, no contexto dos julgamentos de duração, essa associação poderia conduzir a atribuição de fluência a um intervalo de tempo mais longo.

Ambiguidade do julgamento. Uma condição que modula a atribuição de fluência é quando a informação central para o julgamento em questão é ambígua, ou mais difícil de aceder ou discriminar (*ver Figura 2*). O impacto da fluência (baseada na memória) em vários tipos de julgamentos tende a ser maior quando os diferentes níveis da variável a ser julgada são mais difíceis de avaliar (e.g., Dechêne et al., 2010, Novemsky, Dhar, Schwarz e Simonson , 2007, Unkelbach, 2007). A falsa-atribuição da fluência ocorre porque a experiência de fluência é usada para desambiguar as informações relevantes para o julgamento em curso. Por exemplo, no contexto do efeito de verdade, os investigadores usaram afirmações ambíguas porque, se os indivíduos tivessem conhecimento factual sobre essas afirmações, fariam julgamentos de verdade com base nesse conhecimento e menos em informações contextuais, como os sentimentos de familiaridade associados à repetição (e.g., Dechêne et al., 2010).

O mesmo racional pode ser aplicado à perceção do tempo: quando a duração é difícil de ser estimada, a probabilidade de usar informações contextuais aumentará, especialmente se tiver algum valor diagnóstico, como a fluência de processamento parece ter (e.g., Reber et al., 1998; Winkielman & Cacioppo, 2001, Foster, et al., 2015). Vários estudos sobre a percepção do tempo mostraram que a dificuldade no julgamento da duração parece moderar os efeitos não-temporais contextuais nesses julgamentos (Droit-Volet, Fayolle & Gil, 2016, Droit- Volet & Zélanti, 2013; Gómez & Robertson, 1979, Matthews, 2011). Por exemplo, Gomez e Robertson (1979, experimento 1) solicitaram julgamentos de duração (i.e., *rating-scale* de 3 pontos, de curto a longo) de formas geométricas variando em tamanho (i.e., pequenas versus grandes). Dois conjuntos de durações apresentadas intercaladas em blocos diferentes (i.e., conjunto 1: 15, 30, 45 ms, conjunto 2: 15, 85, 155 ms), foram utilizados como uma manipulação de dificuldade de discriminação: fácil (diferenças de 70 ms) e difícil (diferenças de 15 ms). O efeito das características não temporais (i.e., tamanho) foi apenas significativo quando as diferenças de duração (i.e., 15 ms) eram mais difíceis de discriminar. Os autores sugeriram que a dificuldade de discriminação aumenta a probabilidade de usar características percetivas não-temporais para diminuir a incerteza de julgamento temporal. Mais recentemente, Matthews (2011, experimento 1) propôs também um processo de atribuição para explicar por que um efeito de repetição intra-ensaio (ver adiante) diminuiu em função da capacidade de discriminação temporal (medida ao nível individual). Contudo, no limite de nosso conhecimento, não existiram estudos que exploraram a associação de ambiguidade temporal e efeitos da familiaridade em julgamentos de duração.

Constrangimentos à atribuição. A perspectiva de falsa-atribuição sugere que a fluência de processamento inicial emerge como uma experiência subjetiva específica e, em seguida, é atribuída apropriadamente dentro de um dado contexto, principalmente numa situação de avaliação (e.g., Bornstein & D'Agostino, 1992, 1994; Jacoby, et al., 1989, Whittlesea, 1993). Portanto, as atribuições dadas à experiência de fluência são maleáveis e dependerão dos objetivos de processamento (Oppenheimer, 2008; Schwartz, 2004; Whittlesea & Williams, 2000). Uma consequência desse pressuposto é que quando a fonte correta é identificada (*ver Figura 2*), as pessoas não usarão a fluência para suportar o julgamento em curso, principalmente porque o seu valor diagnóstico é perdido (Jacoby & Whitehouse, 1989; Oppenheimer, 2003; Schwarz & Clore, 2007; Whittlesea & Williams, 1998). Por exemplo, foi demonstrado que o efeito de nomes de pessoas (apresentados previamente) serem mais prováveis de serem categorizados como "famosos" do que novos nomes, é impedido de ocorrer quando foram conscientemente lembrados – principalmente porque a fluência de processamento baseada na memória foi corretamente atribuída à sua verdadeira fonte (Jacoby, Woloshyn, & Kelley, 1989).

O efeito de "*discounting*" também foi detetado em julgamentos temporais. Por exemplo, Kleider e Goldinger (2004, experimento 7) solicitaram aos participantes que fizessem julgamentos de duração seguidos (no mesmo ensaio) por julgamentos de reconhecimento de faces desconhecidas e familiares (ou seja, previamente expostas no início da experiência) com durações que variam de 1000 a 2000 ms . Os resultados foram consistentes com a hipótese de correção: o efeito sobrestimado da familiaridade nos julgamentos de duração foi moderado pela precisão das respostas e nulo quando apenas as decisões corretas de reconhecimento foram consideradas. Seguindo uma abordagem semelhante, Paller et al. (1991, experimento 2) encontraram evidência de desconto espontâneo de fluência baseada na memória. Durante a primeira fase do experimento, expuseram os participantes a palavras que foram apresentadas em uma segunda fase, com novas palavras (não repetidas) com duração média de 110 ms. O efeito de familiaridade foi significativo mas, quando as palavras incorretas foram excluídas da análise, um efeito menor foi encontrado.

No entanto, o pressuposto de uma correção ("*discounting*") não significa que será sempre observada. Especificamente, a correção ("*discounting*") só é assumida se a "*atribuição correta*" impede a "*falsa-atribuição*". Essa pode ser a razão pela qual estudos como Masson e Caldwell (1998) e Witherspoon e Allan, (1985), utilizando estímulos de

duração próxima ao limiar percetivo (30 a 60 ms), não mostraram uma clara moderação pela precisão de identificação percetiva.

Uma característica relevante dos julgamentos de duração é que a duração do próprio estímulo pode afetar a consciência da fonte correta da fluência experienciada. Os julgamentos baseados na familiaridade tendem a ser mais fortes quando as condições apresentadas impedem os participantes de ficarem conscientes de que foram anteriormente expostos a estímulos alvo (por exemplo, Bornstein & D'Agostino, 1992, 1994). O efeito de mera-exposição foi mais forte (i.e., preferindo os estímulos repetidos em relação a novos) quando (previamente à tarefa de julgamento) os estímulos foram apresentados subliminarmente (5 ms) comparando com os supraliminares (500 ms). De acordo com a interpretação desses autores, a duração do estímulo torna os participantes mais prováveis atribuir fluência de processamento à fonte correta – a exposição anterior – e menos provável de usá-lo como um indicador para o julgamento de agradabilidade. No entanto, quando os efeitos da fluência foram avaliados em função da duração apresentada (na fase de avaliação), os resultados foram menos claros, com resultados mistos nos julgamentos de agradabilidade (Rashidi, Pazhoohi & Hosseinchari, 2012; Gerger et al., 2011, 2016). Estes dados podem ser o resultado de efeitos opostos, um relacionado à percepção de fonte de fluência (Bornstein & D'Agostino, 1992, 1994) e o outro, a uma fluência crescente em função da duração (Forster et al., 2015, 2016; Reber et al., 1998; Winkielman & Cacioppo, 2001). Gerger et al. (2016) sugere que maiores discrepâncias entre a magnitude da duração do estímulo (por exemplo, 47 e 400 ms em Gerger et al., 2011, e 200 ms e 5000 ms em Rashidi et al., 2012) poderiam induzir os processos de correção. Outros estudos que usaram a duração em um intervalo próximo não encontraram evidências de processos de correção (Foster et al., 2015, 2016). Como a duração dos estímulos é central nos estudos de perceção do tempo, o seu impacto nos efeitos de correção da fluência, torna-se um aspecto crítico a ser explorado. Infelizmente, nos estudos de familiaridade o conjunto de durações objetivas utilizadas pertencem a um range muito específico, sem uma discrepância tão grande quanto a utilizada por Gerger et al. (2016) e Rashidi et al. (2012) noutro tipo de julgamentos.

Familiaridade: fluência percetiva e conceptual

O termo fluência de processamento captura a experiência geral de fluência que pode ser gerada em diferentes níveis de processamento de estímulo. A fluência de processamento engloba uma ampla gama de fenômenos metacognitivos, mas geralmente são destacadas duas

categorias ou níveis: a fluência percetiva e conceptual (Winkielman, Schwarz, Fazendeiro, & Reber, 2003; mas ver Alter & Oppenheimer, 2009. A fluência percetiva é a facilidade de capturar as características físicas e estruturais do estímulo – a identificação da identidade do estímulo e a experiência de clareza e distintividade do percepto – e ocorre em níveis inferiores de processamento. Diferentemente, a fluência conceptual é a facilidade de capturar o significado do estímulo – a clareza da representação do estímulo e sua relação com as estruturas do conhecimento – e ocorre em fases de processamento de nível superior. A fluência de processamento pode ser causada principalmente de duas maneiras: características percetuais (por exemplo, clareza, contraste figura-fundo, tamanho, duração, simplicidade, simetria), que afetam diretamente a fluência percetiva, e experiências anteriores do perceptor (i.e., repetição, conhecimento prévio), que influencia a fluência conceptual (Reber et al., 2002).

Porque a familiaridade é baseada na repetição e no conhecimento prévio, pode simultaneamente gerar a experiência da fluência nestes dois níveis diferentes de processamento; ao processar um estímulo repetido, como uma palavra, por exemplo, os indivíduos não apenas re-acedem às suas características físicas (por exemplo, ortografia) – relacionadas à fluência percetiva –, mas também ao seu significado semântico – relacionado à fluência conceptual. Portanto, nesta tese consideramos importante contrastar o efeito da familiaridade, em comparação com outros tipos de manipulações de fluência, especificamente, aqueles que estão estritamente relacionados com a fluência percetiva. Isto porque os sentimentos de familiaridade não são inteiramente dependentes da memória (i.e., da familiaridade objetiva). Demonstrou-se que a fluência percetiva (gerada por manipulações estritamente percetivas, como o contraste figura-fundo) poderia resultar em sentimentos de familiaridade para os estímulos apresentados, mesmo quando estes são inteiramente novos para indivíduos (e.g., Whittlesea, 1993; Whittlesea et al., 1990). Embora as revisões sistemáticas sejam consensuais com a noção de que a experiência de fluência exerce efeitos semelhantes sobre os julgamentos, independentemente da sua fonte e nível de processamento (e.g., Alter & Oppenheimer, Reber, et al., 2004, Schwarz, 2004), alguns estudos sugerem que a familiaridade pode exercer papéis distintos da fluência percetiva (Silva, Garcia-Marques & Mello, 2015; Garcia-Marques, Silva & Mello, 2016). Isto é particularmente relevante em julgamentos de duração devido à latência de processamento de cada um dos níveis de processamento, percetivo (mais rápido) e conceptual (mais lento). Daí o foco desta tese nesta distinção.

É de salientar que diferentes conjuntos de típicas manipulações de fluência percetiva (ver Alter & Oppenheimer, 2009) são encontrados em estudos de percepção do tempo, tais como o contraste-fundo (Hochhaus, et al., 1991; Long & Beaton, 1981; Mathews et al., 2011), o tamanho (Gomme & Robertson, 1979, Rammsayer & Verner, 2015, Xuan et al., 2007), a complexidade (Aubry et al., 2008; Cantor & Thomas, 1977; Varakin, 2013), *repetition-priming* (Marohn & Hochhaus, 1988; Ono et al., 2007; Zhou et al., 2010), a coerência (Brown & Boltz, 2002; Jones & Boltz, 1989; Horr & Luca, 2015), e ortografia (Chastain & Ferraro, 1997; Devane, 1974; Warm & McCray, 1969). Mas se no geral, essas manipulações experimentais que aumentam a fluência percetiva parecem influenciar o julgamento da duração para uma sobrestimação como as manipulações de familiaridade (que estão principalmente relacionadas à fluência conceptual, algumas dessas manipulações parecem não seguir um padrão convergente (Alter e Oppenheimer, 2009; Reber, et al., 2004; Schwarz, 2004) sendo foco de discussão ao longo desta tese. Por exemplo, o efeito da repetição imediata (isto é, a apresentação repetida do estímulo no mesmo ensaio) é negativo: os estímulos primados repetidos são percebidos como tendo uma duração mais curta do que os estímulos primados não repetidos (Marohn & Hochhaus, 1988; Ono et al., 2007; Zhou et al., 2010). Supõe-se que o *repetition-priming* (imediato) aumenta a fluência perceptiva, facilitando o processamento do estímulo alvo por uma pré-ativação da representação do estímulo (Jacoby, 1991; Kelley & Lindsay, 1993). E, portanto, essas observações parecem contradizer a aparente relação geral entre a fluência (percetiva e conceptual) e a sobrestimação temporal. Essa divergência pode ter importantes consequências teóricas, favorecendo, por exemplo, a necessidade de integração entre campos teóricos e modelos para compreender os fenómenos em estudo e, por outro lado, discutir algumas especificidades da perceção do tempo, se houver.

Tipos de repetição

O efeito de *repetition-priming* (imediato) mencionado segue um efeito bem conhecido na perceção do tempo – *o efeito de repetição* – baseado na apresentação repetida imediata de um estímulo dentro do ensaio de julgamento da duração. Este efeito aparentemente robusto compreende um encurtamento da duração subjetiva do estímulo repetido em comparação com os novos (ver Matthews & Gheorghiu, 2016; Matthews et al., 2014). Tradicionalmente, o efeito de repetição foi encontrado usando o paradigma de *oddball*, onde uma única ocorrência de um (novo) estímulo, apresentada após uma série de repetições de estímulo diferentes

(padrão), é percebida como tendo uma duração mais longa em comparação com os repetidos (New & Scholl, 2009; Pariyadath & Eagleman, 2007; Schindel, Rowlands, & Arnold, 2011; Kim & McAuley, 2013; Tse et al., 2004; Birngruber et al., 2014). Críticas são apresentadas, porque este paradigma confunde repetição com localização na série, favorecendo processos de saliência atencional e expectancy (Tse et al., 2004; Eagleman & Pariyadath, 2009; Matthews & Gheorghiu, 2016; Matthews & Meck, 2016). Contudo, quando distribuições simétricas são usadas (Birngruber et al., 2015a, 2015b; Pariyadath & Eagleman, 2012), ou são comparados condições de *oddball* com repetição e não repetição (Birngruber et al., 2015a, 2015b; Pariyadath & Eagleman, 2012), os efeitos mantem-se. O efeito também é replicado quando são apresentados apenas 2 estímulos em cada ensaio, em condições em que o segundo é repetido ou não repetido (Birngruber et al., 2015b; Matthews et al., 2011; Matthews, 2015; Noguchi & Kakigi, 2006).

Este efeito pode parecer paradoxal, porque a repetição facilita o processamento posterior, indo contra um processo de diminuição de recursos ou de fluência de processamento revistos anteriormente. Uma proposta de explicação é que a repetição imediata está associada a respostas neurais menores– *repetition-suppression* – reflectindo uma eficiente codificação neuronal (i.e., manutenção da ativação da rede neuronal), mas também um processo de adaptação *low-level* percetivo (De Baene & Vogels, 2010; Grill-Spector, Hebson, & Martin, 2006). O nível de ativação ou saliência estaria em relação com a duração subjetiva, menor para os estímulos repetidos (Noguchi & Kakigi, 2006; Pariyadath & Eagleman, 2012; Sadeghi, Pariyadath, Apte, Eagleman, & Cook, 2011). Em conformidade com esta hipótese, quanto maior número de repetições antes de um *oddball*, menor a duração percebida dos estímulos repetidos (Kim & McAuley, 2013; Pariyadath & Eagleman, 2012), e menor o efeito de repetição quando mais diferente for o *oddball* dos estímulos repetidos (Pariyadath & Eagleman, 2012; Zhou et al., 2014).

Um outro modelo proposto por Huber and O’Reilly (2003, see also Huber et al., 2008) – *Pre-Activation/Habituation Model* – explica os efeitos de *repetition-priming* no contexto do reconhecimento e familiaridade, com base numa dinâmica temporal de fluência de processamento. A fluência é definida como o tempo necessário para se atingir a ativação máxima da representação do estímulo. Este processo é beneficiando pela pré-ativação pelo *repetition-priming*. Contudo, este modelo prevê que se o primo tem uma duração longa, pode levar a uma habituação da resposta percetiva, podendo mesmo dificultar o processo de ativação do alvo, e a uma consequente disfluência. Corroborando este modelo, Huber et al.

(2008) demonstraram que o efeito de *repetition-priming* na familiaridade ocorre com durações na ordem dos 100 ms e que pode se inverter com durações do primo mais longas (i.e., 1000ms). No contexto dos julgamentos de duração verifica-se que, por exemplo, o efeito de repetição do *oddball* é nulo com durações de 300 ms (Seifried & Ulrich, 2010) e passa a positivo quando as durações são inferiores a 100 ms (Tse etal., 2004). Outra evidência a favor de um efeito de *repetition-suppression* ou de habituação, é que o efeito negativo de repetição imediata desaparece quando o intervalo entre as duas apresentações do mesmo estímulo são de 2 s (Matthews, 2015, experimento 5). Dúvidas se colocam quanto ao processo que está subjacente a este fenómeno, mas é extremamente relevante entender quais os fatores que o moderam, a sua relação com processo de codificação, habituação e fluência de processamento, sendo que a duração é o fator critico (i.e., o tempo entre os estímulo e a duração do primo).

Capitulo IV: Como Abordar Empiricamente o Efeito da Familiaridade?

Da revisão de literatura apresentada fica claro que duas abordagens distintas têm fornecido evidências empírica que documenta o efeito da familiaridade nos julgamentos de duração. No entanto desde a primeira demonstração do efeito de familiaridade (Warm et al., 1964) todos os estudos apenas têm procurado enquadrar o efeito como manifestação de hipóteses das abordagens específicas. Assim, o efeito tem sido pontualmente referido nas duas abordagens, como evidência de processos atencionais ou de fluência de processamento não tendo sido dada nenhuma atenção específica às suas delimitações. Na realidade, pouco esforço tem sido colocado em perceber a magnitude e a fiabilidade do efeito de familiaridade na perceção do tempo e ainda menos em descobrir os processos subjacentes ao efeito contrastando as duas abordagens explicativas do mesmo.

Os objetivos desta tese são assim os de fornecer a primeira abordagem a integrar e contrastar as duas explicações do efeito de familiaridade. Adicionalmente descreveremos a fiabilidade do efeito quando a manipulação é a de fluência conceptual ou percetiva e procuraremos distinguir o efeito de familiaridade do efeito de repetição.

A base de todo este trabalho é uma meta-análise apresentada no artigo, intitulado "Familiarity effects in duration judgments: A meta-analytic review" (submetido à revista *Psychological Bulletin*, editada pela American Psychological Association). Esta meta-análise permite-nos atingir o objectivo de integração e comparação das duas abordagens explicativas do efeito de familiaridade. Integrando toda a literatura empírica, examinar a fiabilidade do efeito da familiaridade e seus limites. Uma análise crítica de cada um dos modelos permite-nos fazer um levantamento sistemático de possíveis moderadores que sustentam aspectos específicos de cada um dos modelos.

Especificamente, levantamos e testamos a hipótese de que o efeito será moderado por um conjunto de variáveis que que suportam a hipótese atencional (i.e., divisão de recursos atencionais e atenção seletiva), usando as diferentes características dos estudos para definir os contrastes que as permitem estudar. De igual modo levantamos e testámos a hipótese de que o efeito será moderado por diferentes aspectos associados à atribuição da fluência (i.e., discrepância, ambiguidade da informação temporal, e hipótese de "*discounting*") Assim esta analise permite-nos testar se os hipotéticos moderadores de cada um dos modelos afectam na

realidade o efeito, informando-nos sobre a validade relativa de cada uma das duas explicações.

Adicionalmente desenvolvemos dois estudos empíricos onde procuramos testae experimentalmente hipóteses derivadas dos pressupostos dos modelos permitindo contrasta-los.

O artigo, intitulado "Familiarity effects in bias and sensitivity components of duration discrimination" (submetido à revista *Attention, Perception, & Psychophysics*, editada pela The Psychonomic Society), pretende oferecer a primeira evidência empírica a contrastar os dois modelos explicativos. Neste abordamos se o efeito da familiaridade, esperado por ambos os modelos definir-se ao nível do enviesamento do julgamento, se estende também à sensibilidade ao tempo (i.e., discriminação de durações). Este facto é particularmente relevante por ser apenas esperado pelas explicações atencionais enquadradas em modelos de relógio interno.

O terceiro artigo, intitulado "The dynamics of facial electromyography predicts duration estimation" (submetido à revista *Scientific Reports*, editada pela Nature) contrasta os dois modelos usando dois indicadores fisiológicos complementares, um de atenção (i.e., atividade muscular do corrugador superciliar e a variação da frequência cardíaca) e enviesamento por fluência (i.e., atividade muscular do zigomático major). Os indicadores fisiológicos da atenção permitem verificar se esta explica quer as estimativas de tempo (detecção da informação temporal, prevista pelos modelos de relógio interno) e simultaneamente as interferências atencionais supostamente promovidas pro variáveis não temporais (familiaridade). A activação do zigomático major, como indicador de processo afetivo associado à fluência, deverá ter um valor preditivo apenas do enviesamento promovido pela familiaridade e não para a deteção da informação temporal.

Dois outros objetivos serão alcançados através da meta-analise realizada. O primeiro será de contrastar os efeitos na duração obtidos por manipulação de familiaridade versus mera fluência percetiva. A nossa análise contrasta os diferentes moderadores para os dois tipos de manipulação de fluência. Uma explicação dos efeitos de familiaridade apenas com base em fluência pressupõe efeitos similares para manipulações puramente de fluência percetiva. O segundo será o de contrastar os efeitos de diferentes tipos de repetição: a repetição associada à familiaridade (exposição previa à tarefa) ou durante o contexto de julgamento de duração (inter ou intra-ensaio). Deste modo pretendemos clarificar os aparentes efeitos contraditórios identificados na literatura clarificando a necessidade de abordagens explicativas distintas.

Secção II

Secção Empírica

Empirical Article 1

Familiarity effects in duration judgments: A meta-analytical review

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Abstract

The current meta-analysis accumulates empirical findings on the familiarity effect in duration judgments (the duration of more familiar stimuli is judged to be longer than that of less familiar stimuli). Experiments on this effect have been developed within two separate lines of thought (time perception and processing fluency). Here we offer an integration of these two lines of thought, contrasting hypothesis derived from the attentional account in information processing models of time perception with those derived from a misattribtuional fluency account of duration judgments. After examining the reliability of this effect in a meta-analysis of 128 experiments (N=3,338) we test the moderators that we derived from the two accounts with mixed effects categorical models and meta-regression procedures. All analysis integrates and separates duration judgment effects promoted by conceptual and perceptual fluency manipulation in order to understand how processing fluency is able to account for the main effects. Results show that the effect is highly reliable either when associated with conceptual or perceptual fluency manipulations. The analysis supports several and different assumption of both the attentional and the misattribtuional explanation of the effect, suggesting that the effect may occur both in time representation and judgment mechanisms. In addition results clarify the dissociation between moderators of the effect when promoted by conceptual and perceptual fluency. We conclude by discussing implications and future research directions for addressing the effects of familiarity and fluency in duration judgments.

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Key words: Familiarity; fluency; repetition; attention; duration judgments.

Familiarity Effects in Duration Judgments: A Meta-Analytical Review

Introduction

In our daily lives we are frequently faced with an experience of subjective temporal distortions when we encounter stimuli or events that are familiar to us. For example, we all experience the fact that a return trip traveled on a familiar route seems to take longer than the experience of covering that distance over new ground. Also, and oddly enough, familiar words appear to standing longer in the middle of unknown words spoken in a foreign language. A considerable number of experimental studies, using multiple approaches on familiarity operationalization, seem to give strong support to these subjective impressions. Systematically, it has been reported that the duration of more familiar stimuli is judged to be longer than that of less familiar stimuli, either when familiarity is induced by experimentally pre-exposing individuals to those stimuli in different degrees (e.g., Kleider & Goldinger, 2004; Masson & Caldwell, 1998; Ono & Kawahara, 2008; Paller, Mayes, McDermott, Pickering, & Meudell, 1991; Witherspoon & Allan, 1985), or when the chosen stimuli vary already in familiarity to the individual (e.g., Chastain & Ferraro, 1997;; Reber, Zimmermann, & Wurtz, 2004; Reingold & Merikle, 1988; Rhodes & McCabe, 2009; Warm, Greenberg, & Dube, 1964).

The phenomenon is well illustrated by Witherspoon and Allan (1985) experiments showing that induced prior encoding episodes change subsequent duration judgments. Participants judged the exposure duration of briefly presented target words (i.e., 30 to 50 ms) that were read earlier in a previous familiarization task. Duration judgments were longer for words previously studied as compared to new (non-repeated) words. These results were replicated in following studies using similar designs (Kleider & Goldinger, 2004; Masson & Caldwell, 1998; Paller et al. 1991). Another illustration is provided by the first study to identify the phenomena, which rely on pre-experiment familiarity, in this case defined by the frequency of word use in language (Warm et al., 1964). Although words were presented at a fixed actual duration (i.e., 1s) its perception was lengthened for familiar words in comparison to unfamiliar ones. This pattern was replicated several times after (Chastain & Ferraro, 1997; Devane, 1974; Hochhaus, Swanson, & Carter, 1991). The effect occurs also with other types of preexisting familiarity and under a large diversity of experimental conditions. However, conflicting evidence is also to be noted (e.g., Avant, Lyman & Antes, 1975; Ono, Kawahara, & Matsuda, 2004; Schiffman & Bobko, 1977; Thomas & Weaver, 1975).

That literature establishes a relation between familiarity and subjective duration, in a context of prospective timing judgments. That is, in conditions in which individuals know a priori that a duration judgment will be required and so involves the active continuous monitoring of time from onset until stimulus offset (it is not reported in retrospective timing phenomena, in which the individuals are unaware of the duration judgment until after the stimulus offset; see Block & Zakay, 1997; Brown, 2010; Zakay & Block, 2004).

Several features of processing familiar stimuli have been addressed to explain the phenomena. Familiarity emerges from long-term memory stimulus representations, which effect subsequent processing in multiple pathways of cognition (Kahneman, 1973). The familiarity effect has been basically associated with two levels of changes in the processing of non-temporal proprieties of the stimulus: the efficiency in processing such information and the metacognitive fluency experience that arises from that processing (i.e., how fluently the stimulus processing is perceived). The first perspective is anchored in dedicated attentional models of time perception (e.g., Chastain & Ferraro, 1997; Hochhaus et al., 1991), and its relation to a distribution of attention and cognitive resources accounts (Block, Hancock, & Zakay, 2010; Brown, 2008, 1997; Nobre & Coull, 2010; Zakay & Block, 1997, 1996). The second perspective (Kleider & Goldinger, 2004; Masson & Caldwell, 1998; Reber et al., 2004), emphasizes general attribution theories of judgment, based on experiential characteristics as such fluency and familiarity feelings (Alter & Oppenheimer, 2008; Reber, Wurtz, & Zimmermann, 2004; Schwarz, 2004).

Remarkably, since the Warm et al. (1964) first demonstration, many studies have replicated the familiarity effect, but little effort has been put into uncovering its underlying processes, besides placing the effects in one of these specific comprehensive models. In addition the effect has been often been referred to in reviews of time perception literature as a general non-temporal effect in duration judgments (Eagleman & Pariyadath, 2009; Grondin, 2010; Matthews & Gheorghiu, 2016; Matthews & Meck, 2016) with no specific attention given to its delimitations and explanations. Thus, until now it is unclear what is the extent and the reliability of familiarity effect in time perception and the status of its explanations.

In the present work we aim to fulfill such a goal by conducting a meta-analytical review to examine the strength and boundary conditions of familiarity and fluency effects in duration judgments. Thus a first goal of this meta-analysis is to provide an integrative understanding of the effect, offering a reference to future research on the topic. A second goal is to test several predictions of the dedicated models of time perception (i.e., integrating

an attentional account) and the generic models of judgment (i.e., fluency-attribution models), in order to clarify the explanatory status of such mechanisms.

In the following sections of the current article, we review the literature regarding the familiarity effect in duration judgments stressing the specific processes that derived from each of the theoretical models offered as an explanation: attention and fluency-attribution. In addition to those, we will address the assumption of a familiarity effect mediated by fluency in these studies, contrasting manipulations of perceptual fluency, previous knowledge, prior presentation, and the role that inter and intra-trial repetition may exert over the effect.

The familiarity effect

The familiarity effect is here defined as a perceived longer duration for familiar than non-familiar stimuli. In a prototypical study on the familiarity effect in duration judgments, a set of stimuli (e.g., words, faces or shapes) is presented (e.g., one stimulus per second) to participants in the beginning of the experimental session as a familiarization task with no type of judgment. In a second phase of the experiment, some of the stimuli are presented intermixed (between trials) with new stimuli (i.e., not presented previously). In each trial, the stimulus duration that varies between trials (e.g., 0.9, 1.0 and 1.1 s) is immediately judged after its offset (using a rating scale or the psychophysics bisection method for example; for a detailed description of the paradigm see Fernandes & Garcia-Marques, 2012). Results typically show that familiar stimuli (i.e., previous exposure) have higher probability to be judged as longer in duration than unfamiliar stimuli (i.e., unrepeated stimuli) (e.g., Masson & Caldwell, 1998; Kleider & Goldinger, 2004; Witherspoon & Allan, 1985).

The finding that the duration of familiar stimuli are judged to last longer than unfamiliar stimuli (e.g., Warm et al., 1964) has been obtained under many experimental conditions. The effect has been demonstrated using other types of familiarity manipulations besides the mentioned experimental-induced familiarity by previous-exposure (Masson & Caldwell, 1998; Kleider & Goldinger, 2004; Witherspoon & Allan, 1985), and preexisting familiarity by frequency in language selection of words (Chastain & Ferraro, 1997; Devane, 1974; Hochhaus et al., 1991; Warm et al., 1964). Other types of preexisting familiarity have found similar effects, such as words versus non-words (e.g., Reber, Zimmermann, & Wurtz, 2004; Reingold & Merikle, 1988; Taylor & Lupker, 2006), previous knowledge (e.g., Rhodes & McCabe, 2009; Kowal, 1976, 1987), or semantic associations (e.g., Marohn & Hochhaus,

1988; Ono & Kawahara, 2008). It occurs in the visual domain for faces (e.g., Fernandes & Garcia-Marques, 2016a), words (e.g., Warm & McCray, 1969), sentences (e.g., Kowal, 1976), shapes (Ono et al., 2007), or objects (e.g., Schiffman & Bobko, 1977), and in the auditory domain for music (Kowal, 1987). The effect has been shown within different duration ranges, for the millisecond range (i.e., under 100 ms; Stoyanova & Bohdanecky, 1988), for the hundreds of milliseconds range (i.e., under 1 s; Reber et al., 2004), for the second range (Schiffman & Bobko, 1977) or above (i.e., minutes; Avni-Babad & Ritov, 2003). The effect seem to generalize to different temporal tasks, including rating scales (e.g., Masson & Caldwell, 1998), the magnitude estimation (e.g., Stoyanova & Bohdanecky, 1988), the bisection method (e.g., Fernandes & Garcia-Marques, 2016a), or the production method (e.g., Taylor & Lupker, 2006), and others (e.g., Reingold & Merikle, 1988; Ono et al., 2004). Moreover, it also seems to occur in the context of single judgment conditions (i.e., only duration; Hochhaus et al., 1991) and multiple judgment conditions (i.e., judging other characteristics of the stimulus, Kleider & Goldinger, 2004).

Overall, the familiarity overestimation effect in duration judgments appears to be very robust. However, constraint (i.e., the effective moderators) of this effect are unknown, which are relevant as the bases of theory testing and identification of its underlying mechanisms. In the next sections, we will discuss theoretical accounts of the familiarity effect in duration judgments and highlight possible indexes of these theories.

Attentional mechanisms underlying familiarity effects

One explanation that was offered for the familiarity duration effect relies on the assumption that the processing of non-temporal characteristics of the stimulus exerts an "*attentional interference*" in the processing of time (e.g., Chastain & Ferraro, 1997; Hochhaus et al., 1991; Warm & McCray, 1969).

Different attention features or mechanisms have been related to the perception of time. Time perception seems to be dependent upon selective and distributional attention processes and time seem sto be dependent on our capacity of sustaining attention and on the available processing resources (e.g., Brown, 1997, 2008; Coull, Vidal, Nazarian, & Macar, 2004; Nobre & Coull, 2010). Familiarity effects are assumed to rise because the level of stimulus familiarity is associated with an easy and quick processing of the non-temporal features of the stimulus, allowing more attentional resources to be allocated in processing of stimulus

temporal features (Brown, 1997, 2006, 2008; Thomas & Weaver 1975; Block & Zakay 1996; Fortin, 2003; Buhusi, & Meck, 2006).

Evidence supporting this as a explanation has been developed with a dual-task paradigm (but see Brown, 2008; Block et al., 2010, for other paradigms focusing resource allocation manipulation). In this paradigm participants' performance on a task where they have to attend to the passage of time for later judgment of duration is contrasted with performance in such task when they have simultaneously to perform a concurrent task (Brown, 2006; Brown & Merchant, 2007; Zakay, 1998). Zakay, Nitzan, and Glicksohn (1983), this concurrent task may also vary in degree of difficulty (e.g., Brown, 1985; Brown & Merchant, 2007; Zakay, 1989). For instance a concurrent verbal task may vary in such that it implies just reading words (easy), naming objects shown in pictures (intermediate), or providing associates. Results typically show that produced durations are progressively shorter as the difficulty of the concurrent task increases, being longest in the single-task condition. Reviewing 90 prospective studies, Block et al., (2010) found this to be a systematic effect, since there is always a shortening of duration judgments under higher cognitive load.

This pattern of results replicates with different type of concurrent tasks: low-level processing tasks (e.g., perceptive discrimination, target detection, visual search Macar et al., 1994; Coull et al., 2004) and high-level processing tasks (e.g., mental calculus, lexical decision, reading, Brown & Merchant, 2007; Hicks et al., 1976, 1977; Zakay et al., 1983; Brown, 1985, 1995, 1997; Zakay, 1989; Champagne & Fortin 2008).

The role of attention in duration judgments is further supported by studies showing that the amount of attention allocated between (temporal and non-temporal) information sources varies in function of the experimental attentional instructions (e.g., Coull, Vidal, Nazarian, & Macar, 2004; Macar, Grondin, & Casini, 1994; Casini & Macar, 1997; Grondin & Macar, 1992). For example, Macar et al. (1994) demonstrated that when attention was directly controlled by the participant (allocating attention 0%, 25%, 50%, 75%, or 100% to words or to duration, for example, 25% to words and 75% to duration) the subjective duration expanded as attention to timing increased.

The relevance of the attention mechanism to time perception is recognized in models that aim to explain time perception itself. The fact that the decrease in subjective duration is proportional to the distribution of attentional resources has been interpreted as informing that there is a loss (or decrease in detection) of "*temporal information*" with divided attention. And this assumption has been formalized in information processing models of interval timing

(e.g., Creelman, 1962; Gibbon, Church, & Meck, 1984; Taatgen et al., 2007; Thomas & Weaver, 1975; Treisman, 1963; Zakay & Block, 1996).

The information processing models of interval timing (for comparison to other models see, Buhusi and Meck 2005, Grondin 2010, Ivry & Schlerf 2008 and Meck, 1984), assume the existence of a cognitive mechanism available to constantly measure time. The most acknowledgeable of these models is the SET (Scalar Expectancy Theory, Gibbon, Church, & Meck, 1984). In very simple terms, we can define this measurement as operating over three cognitive processes in three different phases: an internal clock, memory, and a decisional process (see Figure 1A). The internal clock operates first and acts as a chronometer that through the action of a switch continuously accumulates temporal units along an episodic target event (which have a beginning and ending marker).

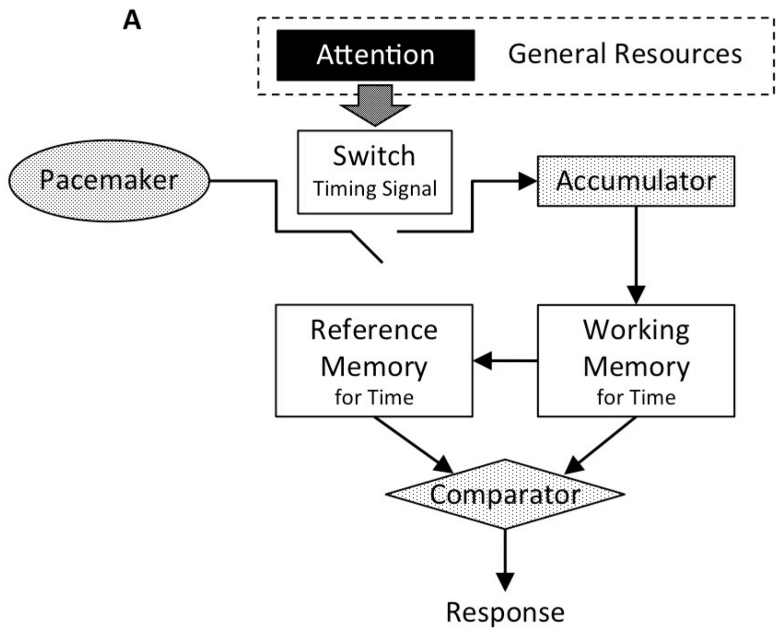

Figure 1A. The architecture of a generic pacemaker-accumulator model of time perception (following Gibbon et al., 1984). A dedicated pacemaker emits time pulses at a specific frequency; the pulses flow into the accumulator when the switch closes, remaining in that state until the end of the interval when it opens again. Attention controls the operation of the switch – the selective and sustained attention to time. The accumulated pulses during a specific interval results in the representation of subjective duration, which may be transferred to working memory and subsequently to long-term memory. The duration judgment (or temporal decision in general) is relative as the product of a comparison between the working memory representation – the current duration – and previous stored representations of

duration (i.e., the reference memory). Partially adapted from "Interval Timing With Gaps and Distracters: Evaluation of the Ambiguity, Switch, and Time-Sharing Hypotheses," by C. V. Buhusi and W. H. Meck, 2006, *Journal of Experimental Psychology: Animal Behavior Processes, 32*, p. 330. Copyright 2006 by the American Psychological Association.

Attention is proposed to control both the action of the switch and the flow of pulses to the accumulator (but see Zakay & Block, 1996). Any interference with attention (e.g. used for other cognitive processes, as in a concurrent task) during the time interval will reduce the number of pusles. The information is lost - pulses are not detected - consequently, time will be perceived to be shorter (e.g., Buhusi & Meck, 2009, Lejeune 1998, Meck 1984, Zakay 1989, Zakay & Block, 1996

The familiarity effect matches this assumption (see Chastain & Ferraro, 1997; Hochhaus et al., 1991; Warm & McCray, 1969), since familiarity is assumed to make stimuli easier to process. Familiarity facilitates generally processing (for instance it facilitates categorization of faces and words, e.g., Bruce & Young, 1998, Christie & Klein, 1995; speeds correct response and reading or naming time of words and sentences, e.g., Scarborough, Cortese, & Scarborough, 1977; Taylor & Lupker, 2006, Kolers & Ostry, 1974; White, 2008). Familiar stimuli impact on attention is documented as providing for quick detection in visual search tasks (e.g., Wang, Cavanagh, & Green, 1994; Lubow & Kaplan, 1997), faster eye tracking fixations and less number of fixations than unfamiliar stimuli (e.g., Althoff & Cohen, 1999; Hsiao & Cottrell, 2008; White, 2008). By demand less working memory capacity (Jackson & Raymond, 2008), familiarity is assumed to free attention resources (Johnston, Hawley, Plewe, Elliot, & DeWitt, 1990; Parks & Hopfinger, 2008) to other goal-driven cognitive processes. Thus within the clock models, familiarity interferes with the temporal switch, leading to a increasing temporal detection, and consequently, a larger accumulation of time units, and thus having stimuli associated with a representation of a longer subjective duration.

Although we would expect the test of the attentional explanatory hypothesis to make use of the dual tasks paradigm described above only one experiment contrasts single and dual tasks performances orthogonally with familiarity (Chastian & Ferraro, 1997).

Chastian and Ferraro (1997; experiment 1, 5 and 6) asked participants to estimate the duration of familiar (high frequency) and unfamiliar words (low frequency) presented during

83 and 167 ms, by using a scale anchored in 1-short and 4-long. Concurrently, participants had to keep in memory some strings of letters (i.e., 1, 2 or 3 letters) in order to perform a recognition test at the end of the task. Duration ratings reflected significant differences between the assumed resources needed to process words with different levels of familiarity, showing a significant interaction between cognitive load and familiarity (Experiment 6) in such that load was more detrimental for unfamiliar than for familiar words (similar familiar resistance to interference was found in *stroop* tasks; Paap & Noel, 1991; Regan, 1981). In this meta-analysis will be able to test the generalization of these results focusing on limited capacity process by comparing the familiarity effects obtained in experimental conditions that ask for a single task (i.e., only duration judgment) with those obtained in experimental conditions that ask for simultaneous multiple judgments of non-temporal features of the stimulus (see *Table 2*)

By assuming the familiarity effect to be related with the process of attention to duration there are specific features that we should expect in that effect. *Figure 1B* helps to understand them.

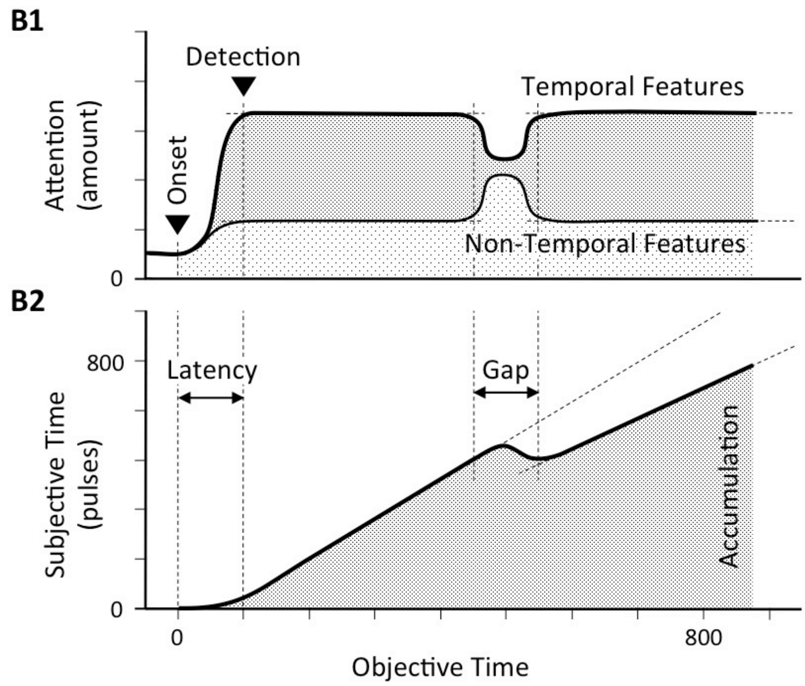

Figure 1B. The predicted effects of attention in subjective time accordingly to switch-accumulation account (following Lejeune, 1999; Buhusi & Meck, 2006); the attention resources as a function of temporal and non-temporal features (panel B1), the accumulation of pulses (i.e., subjective time) as a function of objective time (panel B2). At the sudden onset of

the stimulus to be timed, attention is rapidly and involuntarily oriented toward it (i.e., exogenous attention). The detection of the low-level perceptual features of the stimulus takes a certain amount of time (i.e., latency), which marks the closing of the switch; attention is consciously directed to temporal features, and begins the accumulation process of the pulses emitted by the pacemaker. The sustain attention towards time keeps the constant accumulation of temporal units (i.e., pulses). In parallel, some of attentional resources are involuntary devoted to non-temporal features (irrelevant to the timing task). The controlled process of attention is selective to time, but could be interfered with by salient non-temporal aspects of the stimulus (as late high-level conceptual processes). If attention is (in)voluntarily redirected to these aspects, it creates a gap in the selection of temporal features – the switch opens; the accumulation of pulses is interrupted until the re-initiation of the selective process, and the correspondent re-closing of the switch. The latency of closings and the frequency of openings of the switch will lead to less pulses accumulated and a shortening of subjective time.

A first feature of the familiarity effect relates with if and how familiarity interferes with initial, selection and sustained attention and later attentional processes.

Attention is assumed to impact the initial counting of the internal clock (e.g., Lejeune, 1998), being able to promote a constant bias across any stimuli duration, an "*intercept effect*" (see Mathews & Meck, 2016; Killeen et al., 1997; Eisler, 1979). Familiarity has also been shown to impact "*exogenous attention*" (Posner, Snyder, & Davidson, 1980) in such that what is familiar is quickly detected (e.g., Montani, Facoetti, & Zorzi, 2014). The earlier impact of familiarity is also documented by Event Related Potential (ERP) investigations showing that familiar stimuli are processed earlier (50-200ms) than unfamiliar stimuli (e.g., Hanso, Bachmann, & Murd, 2010; Shtyrov & Lenzen, 2016). For example, Shtyrov et al. (2013) found a differentiation of ERP patterns at 100ms between words and non-words (i.e., unfamiliar) presented in peripheral visual field. Thus it is likely that familiar stimuli promote similar effects of other attention manipulations, impacting the initial counting of the internal clock and promoting a constant bias in their duration, a "*intercept effect*" (see Matthwes & Meck, 2016). Because familiarity makes the early detection of the stimulus faster and more efficient (reducing the variability with which the switch will be triggered), more pulses will be accumulated and time will be overestimated.

But time perception is also dependent upon sustained attention mechanisms. In order to keep track of time, the system needs to sustain attention through all stimulus duration. This

monitoring is very sensitive to any attentional deviation (Brown, 2008). Evidence has shown that changes in attention across duration of stimuli presentation interfere with duration judgments. By promoting gaps in time monitoring (for example by presenting a distractor in the middle of the stimuli presentation) supposedly leading to the closing and opening of the clock switch (see Buhusi & Meck, 2009; Zakay & Brown, 1997), experiments promote sub-estimations that are dependent upon stimuli duration itself. Longer durations are likely to have gaps in the monitoring (Coul, 1998), however, this will be less detrimental for familiar stimuli. As such familiarity effects are likely to be moderated by stimuli duration (see Table 2).

Familiarity is also shown to impact later attentional processes creating differences in processing of repeated and non-repeated stimuli detected in ERP activity at 300-400 ms, (Friederici, 2002; Hagoort, 2008). This suggests that familiarity is also likely to interfere with attention mechanisms associated with the conceptual processing. At this higher time interval we should expect more gaps to occur (Coull, 1998). It is thus likely for the increased familiarity effect with duration ("*slope effect*") to be higher for stimuli process at a conceptual level than perceptual level (see Table 2).

Fluency mechanisms underlying familiarity effects

Another explanation that has been offered to the familiarity effect is one that equates duration judgments to any other type of non-temporal judgments. It is assumed that the experience of familiarity is associated with the feeling of ease of processing able to directly support decisions and judgments (e.g., Kahneman & Tversky, 1973; Schachter & Singer, 1962; Schwartz, 2004). Processing fluency is thus widely assumed to be a metacognitive cue on judgments across a wide range of domains (for a review see Reber, Wurtz, & Zimmermann, 2004; Schwarz, 2004). Some studies have assumed that the same will occur for duration judgments. Short duration judgments just as other quick and highly demanding judgments would also anchor in the subjective experience of ease – or processing fluency – associated with prior exposure (i.e., repetition) (e.g., Kleider & Goldinger, 2004; Reber et al., 2004; Witherspoon & Allan, 1985).

Fluency accounts of familiarity effects on judgments assume that judgments are sensitive to the fluency that arises from processing both the conceptual and the perceptual features of the stimulus (Whittlesea & Leboe, 2003) whatever their relevance to the actual

judgment. Thus even when the experience of fluency does not result from the cognitive operation that objectively contributes to a specific judgment, fluency is likely to be (mis)attributed to the dimension being evaluated (i.e., fluency-attribution hypothesis, Jacoby & Dallas, 1981; see Oppenheimer, 2008). Thus, though the fluency of processing a familiar stimuli could be relevant to memory judgments (e.g. Jacoby, 1981), it also impacts preference judgments (Bornstein & D'Agostino, 1992; Zajonc, 1998), clarity of perception (Jacoby et al., 1988; Whittlesea, Jacoby, & Girard, 1990), the truth of a statement (Begg & Armour, 1991; Garcia-Marques, Silva, & Mello, 2016), the fame of a person (Jacoby, Kelley, Brown, & Jasechko, 1989), and the understandability of a statement (Carroll & Masson, 1992).

The relationship between fluency and duration of a stimulus was noticed by Jacoby and Dallas (1981) who observed that participants spontaneously reported that previous presented words seem to "*jump-out*" of the screen, giving the impression of a longer duration (in the context of near-threshold perceptual identification). This memory-based perceptual enhancement is a feature of perceptual fluency that is able to be mistakenly attributed to duration. This hypothesis was tested by Witherspoon and Allan (1985; see also, Kleider & Goldinger, 2004; Paller et al., 1991) who showed that repeated stimuli (from a prior encoding task) were not only easier to recognize (i.e., the objective fluency) but also perceived to have a longer duration than new (non-repeated) stimuli. Because fluency experience is automatically driven (e.g., Jacoby & Witherspoon, 1982), the need for perceptual recognition or recollection (of non-temporal information) is not necessary for those temporal effects to occur (e.g., Paller et al., 1991; Reber et al., 2004; Witherspoon & Allan, 1985, experiment 2). However, other conditions may favour or modulate the effect.

Figure 2 describes in generic terms, a set of fluency assumptions from different approaches to (mis)attribution process and therefore conditions that are able to modulate its occurrence. By assuming the familiarity effect to be related with fluency effects there are specific features that we should expect to characterize or modulate the familiarity effect.

Misattributions are assumed to occur because objective fluency – the effective processing efficiency – is subjectively experienced. Research has suggested that the subjective experience of fluency is context-dependent, derives from a discrepancy and and as such is a relative processing fluency. This discrepancy approach (Whittlesea & Williams, 1998) see also Whittlesea & Williams, 2001; Whittlesea & Leboe, 2003; Wänke & Hansen, 2015) suggests that the experience of fluency or a feeling of familiarity arises from discrepancy between what level of fluency with which a stimuli is expected to be process and

the actually level of fluency experienced. It is this discrepancy that triggers an attribution process.

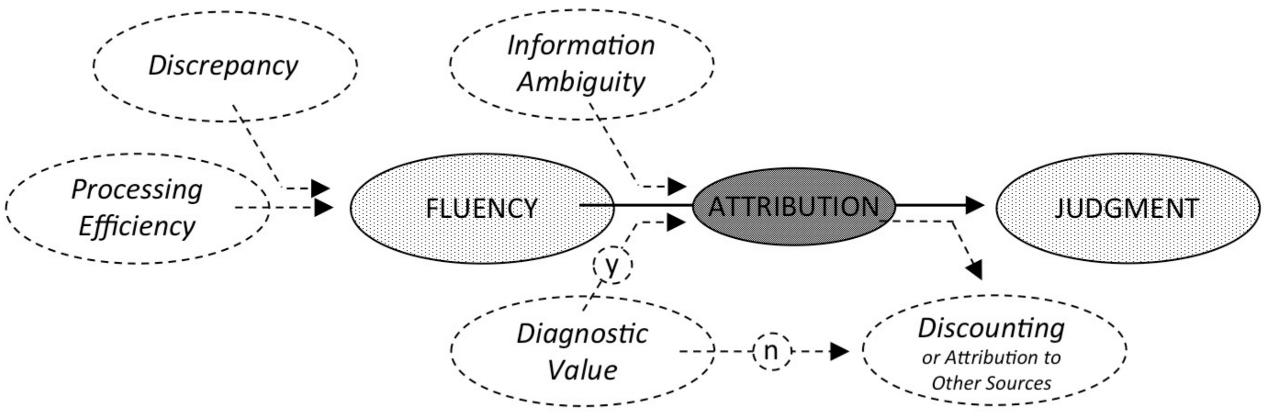

Figure 2. A generic comprehensive fluency-attribution framework (modeled after Jacoby and Dallas, 1981). The metacognitive fluency experience – related with the efficiency of ongoing perceptual or conceptual cognitive processes – is used as information (or a cue) toward judgment, which is mediated by attributional processes. The fluency experience depends on its discrepancy from the context – the relative fluency –, and is more likely to be attributed when central information to the judgment at hand is ambiguous, more difficult to access or discriminate. Attribution is also more likely to occur if the experienced fluency has some diagnostic value to inform that judgment. The diagnostic value of fluency is lost, and fluency "discounted", when its real source could be identified, decreasing its impact on judgment. The central processes (i.e., fluency, attribution and judgment) are the core of the model, partially adapted from "The Secret Life of Fluency," by D. M. Oppenheimer, 2008, *Trends in Cognitive Sciences, 12*, p. 240. Copyright 2008 by Elsevier.

Evidence that the experience of fluency is a discrepancy factor was first provided by Whittlesea and Williams (1998). Authors found that perceived levels of familiarity (promoting more false alarms) where highest for familiar regular non-words than for both familiar irregular non-words and normal words. Apparently, (visually disfluent) regular non-words were surprisingly more fluent than participants expected, and it was the discrepancy regarding those expectations that drove the intensity of the feeling. However, Reber et al. (2004, experiment 5) did not replicate these results in the context of time perception where familiarity was not judged. In that experiment, participants made duration judgments of words and regular and irregular nonwords presented for 32, 48, 64 and 80 ms, and results show

words always to be perceived as lasting longer, and regular non-words to be perceived as lasting longer than irregular non-words. One reason why this replication may have failed is that it is not always clear what is the referential to which our experience of fluency is relative to. Whittlesea and Williams (1998) suggest prior expectations to offer a standard of comparison, but those expectation may rise from either internal references or external references as the ones offered by contextual standard (e.g., Hansen, Dechêne, & Wänke, 2008; Hansen & Wänke, 2015; Laham, Alter, & Goodwin, 2009). Dechêne, Stahl, Hansen and Wänke (2009) show how these contextual standards modulate the "*truth effect*" (i.e., repeated items are perceived as more truthful) which are only observed when repeated items were presented intermixed with new ones, allowing an actual fluency experience dependent on the fluency discrepancy from previous presented stimuli. Similar effects occur when duration is the dependent measure as was shown in two sets of studies. First familiarity effects in duration judgments were shown to be reduced when familiarity is manipulated between-subjects, (Kowal, 1976; Schiffman & Bobko, 1977). As Gomez and Robertson (1979, experiment 1) show, the same occurs with a manipulation of perceptual fluency. Larger stimuli, that are easier to process (i.e., high perceptual fluency), are judged to last longer than small ones (i.e., low perceptual fluency), but only when both stimulus sizes were intermixed in the same experimental session; no differences in duration judgments were found in the between-subjects design. Thus one hallmark of the discrepancy hypothesis is that the stimuli presentation context across trials (i.e., temporal context) modulates the experience of fluency, supposedly because it modulates the salient aspects and expectancy of one stimulus to be compared with the other (e.g., Dechêne et al., 2009; Westerman, 2008; for a discussion see Dechêne et al., 2010; Whittlesea & Leboe, 2003). Contributing to this, we may have factors such as the number the trials and the number of levels of fluency.

In the present meta-analysis we will test the fluency discrepancy explanation of the effects of familiarity-fluency on duration judgments, by testing if the different contextual distribution of stimuli (see *Table 1*) moderates the effect.

Figure 2 signals that this subjective experience of fluency may be integrated in an attributional process dependent upon its relative diagnostic or informative value to duration judgments (Oppenheimer, 2008; Schwartz, 2004; Whittlesea & Williams, 2000). Individuals may have learned to associate fluency to specific outcomes and implement the inferred meaning in future similar contexts. Likely, because the feeling of familiarity is paired with memory (Mandler, 1980; Yonelinas, 2001, 2002), fluency is strongly used as a recognition

heuristic (e.g., Begg et al., 1989; Jacoby & Dallas, 1981; Whittlesea et al., 1990). Its is also likely that because longer exposure period of time allows more fluency of processing (e.g., Reber et al., 1998; Winkielman & Cacioppo, 2001; Foster, Gerger, & Leder, 2015; Forster et al., 2016) fluency becomes a ecologically valid cue for duration.

However that diagnostic value tends to be relative to the availability of the information that is central to the judgment at hand. Fluency seems to be more relevant to the judgment at hand if this central information is ambiguous, or is more difficult to be accessed (e.g., Dechêne et al., 2010; Novemsky, Dhar, Schwarz, & Simonson, 2007; Unkelbach, 2007). For instance fluency impact on perceived truth occurs mainly with ambiguous statements whereas factual knowledge will not interfere with it (see, Dechêne et al., 2010). Also in duration judgments contextual non-temporal effects were shown to be more likely when judgment is more difficult (Droit-Volet, Fayolle, & Gil, 2016; Droit-Volet & Zélanti, 2013; Gomez & Robertson, 1979; Matthews, 2011). Gomez and Robertson (1979, experiment 1) illustrate this phenomena showing that duration judgments (i.e., 3-point rating scale, from short to long) of visual shapes were impacted by the relative size (i.e., small versus large) when time discrimination was more difficult (defined by objective duration difference: 15 ms vs. 70 ms). More recently, Matthews (2011, experiment 1) present the only experiment that directly test the moderation that ambiguity or difficulty in processing duration information exerts over familiarity duration effects. Results show that the effect decreased as a function of duration discrimination ability that was measured at an individual level.

In the present meta-analysis we will address this moderation having as a proxy of ambiguity/difficulty the actual duration differences used within each experiment session. Because duration discrimination difficulty increases with the physical duration (i.e., Weber law), we expected that the effect of the within-study duration-differences used in the experiments will be moderated by the actual physical duration (see *Table 1*).

In *Figure 2* we also stress that the (mis)attribution process may be prevented from happening. When the correct source of fluency is identified, not being relevant to the judgment means people will not use the fluency to support the judgment at hand, mostly because its diagnostic value is lost (Jacoby & Whitehouse, 1989; Oppenheimer, 2003, 2004; Schwarz & Clore, 2007; Whittlesea & Williams, 1998). For instance, the effect showed in a set of studies that previously presented names were more likely to be categorized as "*famous*" than new names, is prevented from happening when these names were consciously recalled

from memory – mostly because memory-based processing fluency was correctly attributed to its true source (Jacoby, Woloshyn, & Kelley, 1989).

This null or discounting effect was also detected in temporal judgments. In Kleider and Goldinger (2004, experiment 7), participants made duration judgments of faces (durations ranging from 1,000 to 2,000 ms) after a recognition judgment (whether or not previously exposed to in the experiment) with sesults showing that the familiarity effect in duration was moderated by recognition accuracy. No effect was detected for correct recognition decisions. Also Paller et al. (1991, experiment 2) found evidence of spontaneous discount of memory-based fluency, showing familiarity duration effects to be reduced when incorrect recognitions were excluded from statistical analysis.

In order to test the prevalence of the discounting effects we will address this effect in this meta-analysis. We predict that familiarity effects in duration judgments will be smaller when concurrent judgments of non-temporal stimuli features are made, making awareness of the correct source of fluency possible, and consequently, the occurrence of discounting effects (see *Table 1*).

A relevant feature of duration judgments is that duration of the stimulus itself may impact awareness of the correct source of the experienced fluency. Familiarity-based judgments tend to be stronger when presented conditions prevent participants to become aware that they had been previously exposed to target stimuli (e.g. Bornstein & D'Agostino, 1992, 1994). Stimulus duration may make participants more likely to attribute processing fluency to the correct source – the prior exposure or other source of fluency – and if that is the case less likely to use it as a proxy for time estimates. In addition, Gerger et al. (2016) have suggested that greater discrepancies between the magnitudes of stimuli duration (e.g., 47 and 400 ms in Gerger et al., 2011, and 200 ms and 5000 ms in Rashidi et al., 2012) could allow a better dissociation of the sources of the feelings inducing discounting processes. Although other studies that used duration in a proximate range they did not find evidence of such discounting processes (Foster et al., 2015; Forster et al., 2016). As stimuli duration is central in time perception studies, its impact in fluency discounting turns out to be a critical aspect to explore in the present meta-analysis. Although no studies (in the literature) manipulated durations that varied widely across different ranges, particularly in the order of milliseconds (i.e., near-threshold of perception) to hundreds of milliseconds, a meta-analysis comparing studies will allow us to answeri this relevant question – we expect that effect sizes will decrease proportionally with duration range (see *Table 1*).

Familiarity as a source of fluency

Both theoretical perspectives presented above to explain familiarity effects in duration judgments assume familiar stimuli to be those that were previous presented. However, the fluency explanation of the effect suggests it can be replicated with sources of fluency other than that of previous presentation. For that purpose we include in this meta-analysis any experiment that documented the effects of any manipulation of processing fluency over duration estimates.

It should be stressed that the term processing fluency captures the general experience of fluency that can be generated at different levels of stimulus processing. But processing fluency encompasses a wide range of metacognitive phenomena, from which two categories or levels are usually highlighted: perceptual and conceptual fluency (Winkielman, Schwarz, Fazendeiro, & Reber, 2003; but see Alter & Oppenheimer, 2009). Perceptual fluency is the ease of capture of the physical and structure features of the stimulus – the identification of stimulus identity and the experienced distinctness of the percept – and occurs at low-levels stages of processing. It may be manipulated through clarity, figure-ground contrast, size, duration, simplicity and symmetry. On the other hand, conceptual fluency is the ease of capture of the meaning of the stimulus – the clarity of stimulus representation and its relation to the structures of knowledge – and occurs at high-level stages of processing. It is usually manipulated through previous experiences of the perceiver (i.e., previous presentation or knowledge). However familiarity based either on repetition of previous presentation and previous knowledge is assumed also to generate perceptual fluency.

Although systematic reviews have suggested that fluency experiences are unitary driving similar effects on judgments independently of its source and processing level (e.g., Alter & Oppenheimer, 2009; Reber, Wurtz, & Zimmermann, 2004; Schwarz, 2004), some research has suggested that familiarity may exert different roles to perceptive fluency (Silva, Garcia-Marques & Mello, 2015; Garcia-Marques, Silva & Mello, 2016). In this meta-analysis will test this assumption with regards to duration judgment, offering the first meta-analytical support for this distinction (see *Table 1*).

Familiarity and Repetition effects

So far we have been focusing on familiarity effects in duration judgments and that previous repetition is usually perceived to be a source of conceptual fluency. However in the

literature it is well documented that this familiarity effect is distinct to the effects that intra-trial repetition exerts over time estimates. The repetition effect on time perception is apparently a robust effect that comprises a subjective duration shortening of intra-trial repeated stimulus in comparison to novel ones (for a review see Matthews & Gheorghiu, 2016; Matthews et al., 2014). The effect has been found for example in the oddball paradigm, where a single occurrence of a (new) stimulus, presented after a series of repetitions of different stimulus (standard), is perceived as having a longer duration in comparison with the standards (New & Scholl, 2009; Pariyadath & Eagleman, 2007; Schindel, Rowlands, & Arnold, 2011; Kim & McAuley, 2013; Tse et al., 2004; Birngruber et al., 2014). Repetition effects patterns of results opposes the one that defines the familiarity effect over duration, whereas a familiar stimulus is perceived to have longer durations than novel ones.

Promoting a within trial repetition the oddball paradigm favors continuous monitoring process of the repetition itself promoting coding efficiency, and favours the salience of repeated stimuli (e.g. Noguchi & Kakigi, 2006; Pariyadath & Eagleman, 2012) as well as the activation of a expectancy of repetition (De Baene & Vogels, 2010; Grill-Spector, Hebson, & Martin, 2006). The relevance of these processes are shown when decreasing the number of repetitions before the oddball (Kim & McAuley, 2013; Pariyadath & Eagleman, 2012), and perceptual distinction of the oddball (Pariyadath & Eagleman, 2012; Zhou et al., 2014) reduce the repetition effect. It is thus clear that the processes underlying the repetition oddball effects and the familiarity duration effect are not the same and should not be confused with each other (Tse et al., 2004; Eagleman & Pariyadath, 2009; Matthews & Gheorghiu, 2016; Matthews & Meck, 2016).

But another paradigm that integrates repetition in the same trial has been associated with the fluency/familiarity effect; the immediate repetition priming paradigm (i.e., repeated presentation of the stimulus immediately before the probe in the same trial; Jacoby & Whitehouse, 1989). Inn this paradigm the effect is negative: primed repeated stimuli are perceived to have a shorter duration than primed non-repeated stimuli (Marohn & Hochhaus, 1988; Ono et al., 2007; Zhou et al., 2010). Huber and O'Reilly (2003, see also Huber et al., 2008) propose that this repetition effect occurs because of a "perceptive habituation" process to the prime, which is broken if the prime presentation is made shorter; negative repetition effects occur only within prime durations of 1000 ms, being inverted (and thus transformed into familiarity effects) when the prime is presented for 100ms (Huber et al. 2008). The habituation hypothesis is also supported by the fact that oddball effects disappear when

stimuli duration is of 300 ms (Seifried & Ulrich, 2010) and become positive with 100 ms durations (Tse et al., 2004). Additionally, when the interval between the repetitions is 2 s we found no repetition negative effects (Matthews, 2015, experiment 5).

It is assumed that immediate repetition priming is just a manipulation of perceptual fluency enhancement, facilitating the processing of target stimulus by a pre-activation of stimulus representation (Jacoby, 1991; Kelley & Lindsay, 1993). If that was the case priming should not be associated with a negative effect, which contradicts the apparent general relation between perceptual fluency and temporal overestimation. This effect will thus be carefully examined in the current meta-analysis (see Table 2). We will focus on delay of repetition as a relevant moderator of repetition effects contrasting immediate repetition (no delay intra-trial); repetition made between trials (delay inter-trial) and the delayed repetition (prior familiarity). Delay inter-trial repetitions was previous shown to have also negative effects in duration (Ono & Kawahara, 2005; Tse et al., 2004, experiment 7; Ulrich, Nitschke & Rammsayer, 2006).

Relevant meta-analysis

There are meta-analytical reviews previously made regarding both the effects of non-temporal factors on duration judgments (framed in time perception literature, e.g., Block et al., 2010; Block & Zakay, 1997) and the effects of processing fluency on other types of judgments (e.g., Bornstein, 1989; Dechêne et al., 2010).

For the present paper we highlight Block, Hancock and Zakay's (2010) meta-analysis which supports the hypothesis of cognitive load attentional effects in duration judgments (Block & Zakay, 1997). One of the six types of cognitive load factors that is defined and compared in that meta-analysis was the degree of novelty-familiarity with the task to be performed, which does not overlap with the goals of our work. Because those authors only studied durations over 3 s, their work prevents a more comprehensive view of the effects of familiarity, especially depending on the types of attentional mechanisms involved. Of the 90 prospective studies included in the meta-analysis of Block et al. (2010), only 10 studies were related to familiarity. In addition these set of studies do not corroborate the familiarity duration effect since they did not reach standard significant effect (d = .26, [-13, +65]),

The Bornstein (1989) and Dechêne et al. (2010) meta-analyses are also relevant as they clarify the effects of prior presentation on preference (mere-exposure effects) and on

truth judgments respectively. Both papers outline relevant moderators of the impact that familiarity/fluency exerts over judgments. Familiarity effects on judgments are more likely to occur with heterogeneous (from repeated and new stimuli) than homogeneous presentation (corroborating the discrepancy hypothesis; Wänke & Hansen, 2015; Whittlesea & Leboe, 2003); that the effects tend to decrease with the reduction of the delay between prior presentation and ratings, being smaller when the ratings are immediate and that effects are greater when the studies use stimuli that are not recognized beyond the probability of chance (both moderations going in favor of a discounting process).

Summary and overview of the meta-analysis

In light of the large number of single studies testing the effects of stimulus familiarity and processing efficiency/fluency in duration judgments, conducted across a wide variety of methodologies and under different theoretical approaches, this meta-analysis provides an invaluable tool for synthesizing the existing knowledge in the dispersed literature. At the same time, we believe this work to provide several insights into the theoretical underlying mechanisms. As discussed above, the familiarity effect in duration judgments could be the product of several mediating mechanisms that occur at different stages and levels of processing. The focus is on the increase in processing efficiency of non-temporal features stimuli and the impact in subsequent processing pathways that interplay with judgment of temporal information. The familiarity effect in duration judgments has been explained by considering changes in the processing efficiency of non-temporal proprieties of the stimulus, basically at two levels: the information processing and the metacognitive fluency experience of that processing. The effect of several moderators could index the way underlying processes are occurring. Meta-analysis is a methodology that allows us to test theoretical predictions, which is relevant because most theoretical predictions were not tested experimentally.

The present meta-analytic review follows non-mutual exclusive processing pathways that stem from distinct fields of research: attentional processes, attributional metacognitive processes and repetition effects.

In table 2 we summarized the moderators offered by the different theoretical approaches that we have been outlining in our review, which represent indicators of theoretical processes underlying the familiarity effect in duration judgments. A small remark must be provided in such that we must have in consideration that these indicators were not experimentally controlled, and thus, have a certain degree of measurement error that should

be taken into account on its interpretation. Nevertheless, the analysis here presented clear ly allows us to organize the literature and to stimulate experimental research.

Table 1. Summary of main theoretical processes and corresponded indexes

Model	Process	Description	Index (Moderator)
Pacemaker-accumulator	Limited capacity	Distribution of attention resources	Multiple judgments
	Selective attention	Detection of stimulus onset by early attention (perceptual processes) vs sustained	Within-study duration
		Interference by late attention (conceptual processes)	Within-study duration x fluency
Fluency-attribution	Discrepancy	Contextual distribution of stimuli (relative fluency and expectancy)	Within vs. between studies
			Levels of fluency
			Number of trials
	Ambiguity	Temporal ambiguity (judgment difficulty and duration discrimination)	Within study duration differences
	Discounting	Conditions for fluency source awareness	Relevant dimension judgment
			Duration range
	Unity of fluency	Consistent effects of different fluency types	Conceptual and perceptual fluency
			Manipulations of fluency
Repetition	Memory, habituation and expectancy	Repetition delay and frequency	Previous vs Intra- trial Repetition

We test all these hypotheses performing three different but related meta-analyses. The first focuses on familiarity effect aiming to state its validity and reliability as well to identify its moderators. The second one isolates as the effect the familiarity/fluency x within physical duration interaction, allowing to test the selective attention mechanism (see *Table 1*). The third one focuses on repetition intra-trial effects versus inter-trial repetition (see *Table1*).

Method

Search strategies and study selection.

We conducted an exhaustive search where multiple strategies were employed to locate studies that provide data on the effects of conceptual and perceptual fluency or repetition in duration judgments.

First, potential studies were identified by searching the following main databases in psychology: PsycINFO via EBSCO, PubMed, Web of Knowledge and Google Scholar. In these searches we used as keywords for the dependent measure, time perception, time estimation, duration judgment, for the independent variables, familiarity, perceptual fluency and repetition, for its manipulation types, frequency in language, words and non-words, expertise, previous exposure, conceptual priming, repetition priming, complexity, contrast, size, time coherence, word length, case, and other types of fluency or its manipulation (terms) listed in various reviews in the field (Reber, Wurtz, & Zimmermann, 2004; Schwartz, 2004; Alter & Oppenheimer, 2009). The search was done for truncated or synonymous terms of these expressions and also for combinations of terms of dependent measures, independent variables and types of fluency and its operationalization. Second, we consulted some relevant review articles in the field (e.g., Matthews & Meck, 2014; Grondin, 2010; Matthews & Gheorghiu, 2016) including the meta-analysis of Block and co-authors to identify additional relevant studies. Sections of references of all articles included in the meta-analysis were screened with the same purpose. Third, these databases were searched with the names of researchers with several publications in the field to identify more studies by the same authors (e.g., William Matthews, Fuminori Ono, Thomas Rammsayer). Fourth, we performed a descendant search in Web of Knowledge to identify articles that cite some relevant articles of each of the independents variables (e.g., Witherspoon & Allan, 1985; Rose & Summers, 1995). Fifth, we hand-searched journals that regularly published articles on the subject (Journal of Vision, Attention Perception & Psychophysics, Journal of Experimental Psychology, Acta Psychologica, Memory & Cognition). Sixth, Consistent with other recent meta-analysis (e.g., Block et al., 2010, Aldao et al., 2010), we did not include PhD dissertations or master's thesis (e.g., Johnson, 2014; Stoup, 1979), and unpublished presentations in conferences (e.g., Kowal, 1984), restricting the selection of studies to peer-reviewed journals. The concern for file-drawer effect should be reduced because few studies were found (k=6), including other languages (i.e., Spanish, Portuguese, French and German).

After this we conducted another round of database searches with fluency categories identified including the common experimental manipulations.

A total of 530 potential articles were full read and analyzed for study eligibility.

Inclusion and exclusion criteria

We used the following criteria to select studies for inclusion or exclusion in the present meta-analysis:

1. To be included in the current meta-analysis, a study had to rely on prospective duration judgments. Retrospective studies were excluded (but reported elsewhere in a publication being prepared), because they involve other mechanisms (for a discussion see Block, 1985; Ornstein, 1969).
2. Only experimental data published until September 2016 from healthy individuals were included in the meta-analysis. When clinical populations with some form of health or psychopathology were accessed, studies were excluded (e.g., Mo, Kersey, & Lowe, 1977), and including in the meta-analysis only when a control group was reported (e.g., Paller et al. 1991). Studies conducted with children or adolescents less than 18 years were excluded (e.g., Avant et al., 1977). The excluding criterion was used for studies conducted with primates or other animals (e.g., Sadeghi et al., 2011).
3. Studies should report duration judgments as a dependent measure involving any temporal task (i.e., estimation, discrimination, production and reproduction) excluding those, reporting different types of temporal experience or prospective time (e.g. time-to-touch).
4. Relative accuracy measurements such as duration ratios in time reproduction and production tasks (i.e., time performance / actual time duration) were included because these relative errors allow us to know the direction of the effect and its magnitude (e.g., Brown & Boltz, 2002), although they represent only 1.5% of the entire set of studies (k=2). Otherwise, absolute errors in these mentioned tasks or error proportions in time discrimination tasks were excluded.

5. When data from the same participants were reported in different published studies, only one was selected, favoring the most detailed (e.g., Kowal, 1987 instead of Kowal, 1984).

6. The difference between conditions with at least two distinct levels of fluency (e.g., non-familiar versus familiar, Kowal, 1976) or two distinct levels of repetition (e.g., no repetition versus a repetition, Matthews et al., 2011b) could be evaluated and tested. No studies were included whose designs did not allow disambiguating the effects of fluency or repetition from other irrelevant independent measures (e.g., Rose & Summers, 1995), or the specific impact of moderators (e.g., temporal tasks, Kowal, 1987). Particularly, studies reporting immediate repetition manipulations as using the oddball paradigm were excluded if they only reported comparisons between repeated items (standard) and non-repeated items (oddball) within each trial. Because several reasons like time-order-effects could be responsible for the effect (Matthews & Gheorghiu, 2016; Matthews & Meck, 2016), we only included oddball studies that compared different oddball conditions, with an oddball equal to standard and an oddball different (or less similar) from the standard (e.g., Birngruber et al., 2015a, 2015b; Pariyadath & Eagleman, 2012).

7. When manipulations used stimuli that were a clear confounding with other non-temporal dimensions, these studies were discarded (e.g., North & Hargreaves, 1999). Whenever it was possible to make the contrast of interest from the statistics, these studies were included (e.g., Masson & Caldwell, 1998).

8. Study report data that allowed calculation of an effect size from statistics as t, F, or p-values, and simultaneously also it allow determining its specific direction.

9. For reduction and control of attentional interference in this meta-analysis (see introduction), we favored the implicit manipulation of fluency, i.e., passive processing of stimuli, and judgments made exclusively at the end of each trial (and only for the duration of the stimulus).

10. Studies were excluded when processing fluency (or difficulty of processing) was manipulated as the cognitive task, in which participants would have to

execute a procedure or sort the information (i.e., multiple items) displayed during the specific interval to be timed. For example, studies varying the complexity of items to be sorted during the interval (e.g., Arlin, 1986; Macar, 1996; Craik & Hay, 1999), words associated or not associated with each other, fluency encoding (Friel & Lhamon, 1965), recognition of familiar and unfamiliar words and faces (Hicks & Brundige, 1979). In situations when the judgment of non-temporal aspects of stimuli were performed only after the trial, we considered these as control studies (regarding theoretical hypothesis earlier mentioned), being either relevant temporal dimensions (i.e., directly related to the fluency manipulation, e.g., evaluation of the size of the stimulus, ref.) or irrelevant (i.e., not related to the fluency manipulation, e.g., identification of stimulus versus frequency in the language, ref.). These studies were coded in a sub-set and compared meta-analytically for theoretical purposes (see next section).

11. Studies whose manipulation of stimuli was only on the level of representation and not the dimension itself were excluded. For example, Arabic numbers (i.e., "9" greater than "3") instead of stimulus physical size (e.g., Xuan et al., 2007, 2009). Furthermore, we also excluded studies in which the processing fluency was measured as a characteristic of the individual (e.g., Barash et al., 2000; Droit-volet et al, 2013) rather than experimentally manipulated.

A total of 78 articles were included in this meta-analytical review, reporting on 161 studies overall. For the fluency meta-analysis 63 articles and 128 studies entered in the data set, from which 56 provided suitable data for estimating fluency x duration interaction effect sizes comprising the second meta-analysis. For the repetition effect in duration judgments meta-analytic study, a sub-set of 66 studies from the fluency data set was included, plus 34 new studies, some reported in an additional 15 articles. Another 8 effect sizes were calculated to address a specific test of the accuracy moderation in duration judgments. In total, 249 effect sizes were included in the current meta-analytic review.

Coding Procedures

We coded any generic available study characteristic that could be a potential moderator, including but not limited to theory driven indexes mentioned early. The authors

developed a coding system that specifies the coding variables and the possible codes for classification of the studies. All moderating variables are described and operationalized in Table 2. Eligible studies were coded for all moderating variables by both authors using the above coding system. Due to the large number of studies included in the present meta-analysis (k = 162), authors coded only 15% of the studies (k = 24) in order to obtain an inter-coder variability measure. Across all variable moderators, the Cohen's Kappa varied between .87 and .94. All disagreements were discussed and resolved, and the final coding in the meta-analysis reflects the consensus between coders.

Non-temporal characteristics

Fluency type and experimental manipulations. Two main types of stimuli manipulation were coded and separated in all analysis: manipulation of conceptual fluency (familiarity) and of perceptual fluency. Because each of these types of fluency could be induced through different procedures and involving different stages of conceptual and perceptual processes (e.g., Reber et al., 2004; Wurtz et al., 2008), we also coded for type of manipulation (see *Table 2*). Five categories grouped the different manipulations of conceptual fluency: frequency in language (e.g., Warm et al., 1964), words vs. non-words (e.g., Reber et al., 2004), previous knowledge (e.g., Kowal, 1987), previous exposure (e.g., Witherspoon & Allan, 1985), and conceptual priming (e.g., Marohn & Hochhaus, 1988). Six categories group the different manipulations of perceptual fluency: repetition priming (e.g., Marohn & Hochhaus, 1988), stimuli complexity (e.g., Schiffman & Bobko, 1974), contrast foreground-background (e.g., Long & Beaton, 1981), physical size (e.g., Cantor & Thomas, 1976), time coherence (e.g., Kowal, 1981), word length and letter case (e.g., Warm & McCray, 1969). The majority of these categories were chosen straightforward from the information given from the researchers; other consisted in more heterogeneous manipulations that were grouped to form a coherent construct with the number of studies sufficient to apply meta-analytic statistics. The complexity category included very different definitions, like number of changes in a sequence of items (Schiffman & Bobko, 1974), entropy (Cardaci et al., 2009), or ambiguity (Chastain & Ferraro, 1997). Word length and letter case manipulations were pooled together in a supra-category of orthography fluency (associated with an early perceptual stage antecedent of lexical and semantic processing). And the contrast foreground-background category was composed of two types of manipulations: the perceptual distinctness (salience)

from the background (e.g., Matthews et al., 2011a), and stimulus degradation with partial backward masking (e.g., Avant & Lyman, 1975).

Contextual distribution of stimuli. Given that the discrepancy and expectancy of fluency impacts the experience of fluency, (Dechêne et al., 2010; Hansen & Wänke, 2015; Westerman, 2008; Whittlesea & Leboe, 2003) and the number of trials impacts attentional resources (see Block et al., 2010), we analyze the way objective levels of familiarity was experimentally distributed across trials coding it several aspects (see Table 2). Studies were coded as within-items presentation of intermixed high-fluent and low-fluent stimuli (heterogeneous condition), or between-items presentations in different sessions of each level of fluency (homogenous condition). Because this discrepancy is based on the average fluency as a comparison standard (Dechêne et al., 2009, 2010), we also coded for the number of objective levels of fluency within-session. But by increasing the number of fluency levels, we also increase heterogeneity and variability making comparisons more likely and so more discrepancy context effect. We contrast studies using two levels (e.g., Witherspoon & Allan, 1985) with those using more than two levels of objective fluency (e.g., Hochhaus et al., 1991)). A number of trials were also considered because they were likely to promote changes in fluency-expectation, supposedly by habituation processes (see also for capacity explanation, Brown & Bennett 2002; Brown, 1998). Based on the distribution across studies, we used 100 trials to define two categories: under and above 100 trials. Critically, it is to be noted that statistically increasing the number of trials could result in higher measure precision and consequently a better estimation of the effect size (Brand et al., 2011).

Modality and stimulus type. We coded the modality of the stimulus (i.e., visual or auditory), because, besides there being evidence of sensory dependence of temporal processing (Penney, Gibbon, & Meck, 2000; Ivry & Schlerf, 2008), the use of auditory stimuli is normally dynamic, unfolding over time, which could by itself impact fluency perception (e.g., change heuristic, Leboe & Mondor, 2008). Additionally, we coded the type of stimuli in function of its implicit proprieties as non-semantic versus semantic properties.

Repetition. Repetition can be manipulated before the temporal task or within that task (intra or inter-trial) being associated with different levels of delays from the judgment to be made. When the type of repetition is intra-trial the effect of repetition in time perception is different from the familiarity/fluency duration effect (Huber et al., 2008; Matthews & Meck, 2016; Matthews et al., 2014). In order to test this delay modulation of the repetition effects we coded repetition type delay in 3 categories: immediate repetition (intra-trial), delayed

repetition and inter-trial repetition (see Table 2). The third category is an intermediate delay condition that serves to control two methodological aspects: a pre-trial exposure comparable to the first category (i.e., delayed repetition) and an intra-experimental repetition comparable with the second category (i.e., immediate repetition).

Temporal characteristics

Duration range. Distinct processes could control the timing in function of duration range (mean value of actual durations used in the study), and modulate effects of non-temporal variables in duration judgments (Buonomano, Bramen, & Khodadadifar, 2009; Fraisse, 1984; Grondin, 2010; Lewis & Miall, 2003, 2009; Penney & Vaitilingam, 2008; Rammsayer & Lima, 1991; Rammsayer & Ulrich, 2011). The value of range of duration used in each study is related to the difficulty of processing the different features of the stimuli and so allow to better or worse identification of the source of fluency. Several findings suggests that below 100 ms, controlled monitoring processes have little impact in duration judgments in contrast with supra-second durations (e.g., cognitive load, Rammsayer & Lima, 1991; Rammsayer & Ulrich, 2011). The transition between sensory/automatic to cognitively controlled timing have been proposed to occur after 100 ms and extended to several milliseconds (Buonomano et al., 2009; Grondin, 2010; Lewis & Miall, 2003; Michon, 1985; Rammsayer, 2008; Spencer, Karmarkar & Ivry, 2009). Thus, we defined 3 duration ranges: under the millisecond range (i.e., < 100 ms), hundred-millisecond range (i.e., < 1000 ms), and supra-second range i.e., > 1,000 ms).

Duration differences. As discussed earlier, fluency attributions tend to occur when focal information to the judgment at hand is more difficult to assess or discriminate (e.g., Dechêne et al., 2010; Gomez & Robertson, 1979; Novemsky et al., 2007; Unkelbach, 2007). In order to examine the informational ambiguity assumption in the context of fluency effects in duration judgments, we created 3 categories of mean difference between physical durations used within session: zero differences (only one duration used), under 100 ms, and above 100 ms. This principle was applied not only to psychophysical discrimination paradigms, where comparisons are explicit, but also to other types of temporal tasks involving estimates, where comparisons are implicit. Categorical or estimation judgments are performed based on an implicit standard reference constructed over the session (based on all encountered durations), and adjusted to the measurement scale (Morgan, Watamaniuk, & McKee, 2000).

Table 2. Coding system for individual studies.

Variable			Coding description
Sample size and year			
N *Experimental and control*			Sample size for which a effect is reported
Year			Year of publication
Non-Temporal Characteristics			
Fluency type and experimental manipulations			
Conceptual fluency	*Frequency in language*	F1 =	Familiarity of words determined by the frequency of its use in the language
(Familiarity)	*Words vs. non-words*	F2 =	Familiarity and processing fluency of words higher than for the non-words
	Previous knowledge	F3 =	Familiarity of stimulus known by individuals prior to the study
	Previous exposure	F4 =	Familiarity of the stimulus presented in different levels before the test phase
	Conceptual priming	F5 =	Within-trial presentation of a related word immediately preceding the target word
Perceptual fluency	*Repetition priming*	F6 =	Pre-activation by a previous within-trial repetition of the target stimulus
	Complexity	F7 =	Representation hampered by the complexity or ambiguity of the stimulus
	Contrast	F8 =	Physical perceptual fluency enhanced by stimuls contextual clarity
	Size	F9 =	Physical perceptual fluency enhanced by stimulus relative size
	Time coherence	F10 =	Temporal fluency of a stream of music notes or sequence of images
	Word length and letter case	F11 =	Lexical and orthographic fluency affecting how easely words are processed
Contextual distribution of stimuli			
Heterogeneity	*Between*	B =	Between-subjects experimental manipulation of fluency
	Within	W =	Within-subjects experimental manipulation of fluency
Levels of fluency	*Two*	L0 =	Only two levels of (low versus high) fluency
	More than two	L1 =	More than two levels of (increasing) fluency
Number of trials	≤100	N0 =	Equal or less than 100 trials within experimental session
	>100	N1 =	More than 100 trials within experimental session
Modality and stimuli type			
Visual	*Semantic*	VS =	Words or sentences in printed form
	Images	VI =	Visual scenes, shapes, figures, objects or human faces
Auditory	*Semantic*	AS =	Words or sentences in auditory format
	Isolated sounds and music	AI =	Isolated sounds varying in pitch or frequency, and music excerpts
Repetition			
Repetition type (delay)	*Previous to experiment*	R0 =	Repetition of the stimulus presented previously to the test phase
	Inter-trials	R1 =	Repetition of the stimulus in successive blocks or trials
	Intra-trials	R2 =	Repetition of the stimulus within the same trial
Number of stimuli per trial	≤50%	N0 =	Proportion of stimuli per trial equal or below 50%
	>50%	N1 =	Proportion of stimuli per trial above 50%
Temporal Characteristics			
Duration range	≤100 ms	G0 =	Mean of all judged durations equal or below 100 ms
	≤1000 ms	G1 =	Mean of all judged durations equal or below 1000 ms
	>1000 ms	G2 =	Mean of all judged durations above 1000 ms
Duration differences	=0 ms	M0 =	The mean of differences between all judged durations equal to zero
	≤100 ms	M1 =	The mean of differences between all judged durations equal or below 100 ms
	>100 ms	M2 =	The mean of differences between all judged durations above 100 ms
Measures and judgments			
Temporal task	*Estimation*	E =	Temporal ratting scale, magnitude or verbal estimation
	Reproduction	R =	Reproduction of the target interval
	Production	P =	Production of a given duration
	Discrimination	D =	Comparative judgments (pair or multiple comparisons, bisection, signal detection)
Multiple judgments	*Duration only*	T0 =	Only duration is evaluatted
	Irrelevant dimension	T1 =	Duration and other irrelevant non-temporal dimensions of stimuli are evaluatted
	Relevant dimension	T2 =	Duration and the target non-temporal dimension of stimuli are evaluatted

Measures and judgment

Temporal task. As mentioned previously, temporal tasks could imply different cognitive processes that can moderate the impact of contextual variables (Grondin, 2010; Lewis & Miall, 2003; Matthews, 2011; Zakay, 1990). In this way, we coded for the 4 main types of tasks used in the field of temporal perception – estimation, production, reproduction, and discrimination (Fernandes & Garcia-Marques, 2012; Grondin, 2010; Zakay, 1990). The reproduction and production methods (included in the present meta-analysis) are the common methods, wherein the judgment is made by generating a duration ("*interval*") (by marking the interval onset and offset): producing a duration ("*interval*") based on a previously specified objective duration (e.g., 1s, Mathews et al., 2011b), or reproducing the duration of a stimulus presented immediately before (e.g., Verner & Rammsayer, 2012). As types of temporal estimation task, we included the verbal estimation task, in which the participants translate the subjective duration into temporal units (e.g., seconds, Cardaci et al., 2009), magnitude estimation task, in which the participant is familiarized with an interval with a certain duration that represents the temporal unit, and the duration estimation being made as multiples of that temporal unit (e.g., Avni-Babad & Ritov 2003), and rating scales, usually ranging from short to long duration (i.e., extreme points), using 1 (e.g., Masson & Caldwell, 1998) to 7 intermediate points (e.g., Reber et al., 2004), by which participants relatively estimate the stimulus duration. As discrimination tasks (i.e., method of comparison), the method of constant stimuli comparison was included, wherein the duration of a stimulus is directly compared (i.e., shorter or longer) with one standard stimulus (e.g., pair comparison, Horr & Luca, 2015) or with a series of standard stimuli (i.e., oddball, Kim & McAuley, 2013) presented immediately before within-trial, the single-stimuli method (e.g., bisection task), which consists of comparing a duration (varying from trial to trial) of the stimulus with two categories of durations (short or long) learned before the task (e.g., Varakin, 2013), and the signal detection method that is similar to the method described before but wherein the durations of the stimulus varies between only two categories, short or long (e.g., Whittlesea, 1993).

Multiple judgments. Implicit and explicit evaluations of non-temporal features of the stimuli are expected to compete, in different degrees, for attention resources allocated to time (Brown, 2008; Buhusi & Meck, 2009; Nobre & Coull, 2010). On the other hand, in a framework of attributional models of fluency, concurrent judgments of non-temporal features

enhances awareness to dimensions that are related to source of processing fluency thus inducing other meta-cognitive processes, such as fluency discounting (Oppenheimer, 2003, 2004; Schwarz & Clore, 2007; Whittlesea & Williams, 1998). We therefore coded studies wherein participants only judged duration (i.e., single task), and studies wherein the participants were asked to simultaneously judge duration and other non-temporal dimensions of the stimulus (i.e., multiple judgments). Because familiarity and fluency effects in duration judgments are related to a specific feature of the stimulus (e.g., word and non-word, Taylor & Lupker, 2006), it would be significant if concurrent non-temporal judgment are relevant or irrelevant to the active processing of that critical feature. Thus we coded non-temporal judgments as relevant (e.g., repetition versus recognition, Kleider & Goldinger, 2004) and irrelevant (e.g., physical size versus perimeter, Cantor & Thomas, 1977).

Duration x Fluency. As already stated, “intercept effects” (based on early selective attention processes) and “slope effects” (based on late attention or constant interference processes), could be driven respectively by perceptual and conceptual processes (see Matthews & Meck, 2016). Because these kinds of effects have been addressed within-study and within-duration-range, we examined fluency versus physical duration moderation by calculating directly the effect size within each study. We excluded studies that used discrimination tasks in which the correspondent psychophysics functions have non-linear distributions as those in bisection paradigms (i.e., logistic distribution).

Computation of effect sizes

Familiarity/fluency meta-analysis. The 151 effect sizes were calculated as Hedges’s g. Given that a significant number of studies in our data set contained small samples less or equal to 10 participants (k = 16, 13%), we used Hedges’s g instead of Cohen’s d which tend to overestimate the true effect size (Field & Gillett, 2010; Borenstein, 2009). The contrast of interest – the difference between high fluent and low fluent stimuli – was examined through within-subject designs in 122 out of 128 studies (96%). Almost every study included in this meta-analytic review reported a t (k = 25, 20%) or F statistic (k = 96, 75%) and no standard deviation (or standard error) for between or within-subjects comparison conditions. Thus, effect sizes were estimated directly or indirectly from these statistics and other few different statistics (i.e., z and Wilcoxon T test) using formula reported in Borenstein (2009). In specific case of F statistic, we proceed first by computing MSE then converting it to pool sample standard deviation, which was used to standardize the difference of means in experimental

conditions (Hedges & Olkin, 1985). In some cases, the appropriate F statistic was not given and thus calculated indirectly by reconstructing the ANOVA table (e.g. Mondillon et al., 2007) using Winer, Brown and Michels (1991) formulas. Because a large part of the F statistic had more than one degree of freedom (i.e., df numerator), the effect size for the contrast of interest was estimated through the maximum possible contrast F method (MPC-F, Rosnow & Rosenthal, 1996). To confirm the calculus of Hedges's g using MSE approach, we also perform the MPC-F procedure, which is also suitable for df = 1 cases (i.e., correlation = 1, Rosnow & Rosenthal, 1996). When possible, we separately calculated effect sizes for different levels of the mentioned moderators using the MPC-F procedure (i.e., it was the case in 23 studies). In multi-factor between-subject designs (k=6) we adjusted the effect sizes calculated from F and t values as recommended by Morris and DeShon (1997). Because in within-subject studies it is unusual to report correlations between the observation of each condition, we have chosen to follow a common practice assuming a correlation of .5 (Borenstein, Hedges, Higgins, & Rothstein, 2009). The variance of Hedge's g was calculated using formula reported in Borenstein (2009). The effect size was defined as positive if duration judgments were larger for high fluent stimuli than for low fluent stimuli. Following the conventions of Cohen (1988), the effect sizes can be interpreted as small with g = .2, medium with g = .5 and large with g = .8.

Duration x fluency meta-analysis. In the second meta-analysis examining fluency versus physical duration interaction effects (i.e., sub-set of studies of the primary meta-analysis), all of effect sizes were estimated from contrast' F statistic (i.e., mean sum of squares contrast divided by MSE, Wiener et al., 1991). If the interaction was reported as being non-significant but no F statistic was given, we computed the effect size by assuming p = .5, following a conservative approach recommended by Rosenthal (1991). A total of 56 effect sizes were calculated, with 19 estimated from non-reported statistics when no sufficient data was available to reconstruct the ANOVA table. The effect size was defined as positive if fluency effect in duration judgments (i.e., high minus low fluency) is larger at longer durations than in shorter durations.

Repetition meta-analysis. The mentioned effect size estimation procedures were followed in the repetition meta-analytic study. A total of 100 effect sizes were calculated from t and F statistics. The effect size was defined as positive if duration judgments were larger for (more) repeated stimuli than for less or unrepeated stimuli.

Meta-analytic procedures

Weighting average effect size. In order to diminish the risk of distorting the average effect sizes, each individual study effect size was weighted by the inverse of its variance – more precise effect sizes have larger weights (Hedges & Olkin, 1985; Hedges & Vevea, 1998).

Within and between-subjects effect sizes. It is controversial to compare between and within-subjects designs in a meta-analytic methodology (Dunlap, Cortina, Vaslow, & Burke, 1996; Morris & DeShon, 2002). Thus we conducted all meta-analyses both including and excluding between-subjects designs, which are fewer in number (i.e., k = 6 from 128 studies in the overall meta-analysis), but no distortions were detected. Therefore, for the completeness of study sample, we decide to report meta-analysis with between-subjects designs. But, to investigate the possible differential effects of contextual distribution of stimuli represented by homogenous and heterogeneous conditions (i.e., low versus high fluent stimuli), we performed separated analyses to between-subjects and within-subjects fluency effects.

Combination of multiple effect sizes within studies. Many of the studies that we included in this meta-analytic review contributed with more than one effect-size, depending on the levels of the moderating variables. However, the statistical requirements in the meta-analysis methods assume the independence of samples, which is violated if multiple effect sizes from the same study are included (e.g., Card, 2012, Cooper, 1998, 2009). In order not to exclude relevant information, we followed a strategy that is frequently used to manage effect sizes that are statistically dependent - the shifting unit of analysis (Card, 2012; Cooper, 1998, 2009), although there are some objections that this type of violations does not affect statistical precision (e.g., Tracz, 1985; Tracz, Elmore, & Phlmann, 1992). In this approach, each relevant effect size associated with a study is coded as if it was independent. The unit of analysis determines how these effect-sizes are aggregated as a weighted average. For example, a study may contribute with 3 effect sizes for the type of fluency manipulation (e.g., words versus non-words, contrast figure-ground, and frequency in language, Hochhaus, Swanson, & Carter, 1991); effect sizes are weight averaged to calculate the overall effect size of processing fluency – the unit of analysis will be the study. If the analysis is to test potential moderating variables, such as the fluency type (i.e., conceptual vs. perceptual), each study may contribute an effect size for each level of the moderator in maximum, in this case, words

versus non-words and frequency in language are weight averaged (i.e., conceptual) - the unit of analysis is the category of the moderator. The shifting unit of analysis procedure allowed us to retain as many data points as possible from each study, while reducing any violations of statistical independence assumptions.

Random-effects model for general analysis. For overall mean effect-size calculation we ran the more commonly employed Random-Effect (RE) models (Borenstein, 2009). This meta-analytical solution assumes that effect sizes in meta-analysis are randomly sampled from a population of possible effect sizes, and thus conclusions could be generalized to studies not included in the meta-analysis (Field, 2003; Hedges & Vevea, 1998), as assumed in the discussion of the present review. RE models also offers the advantage by assuming a true variability in effect sizes – the observed variability in the sample of effect sizes included in the analysis depends both from sampling error and from differences between the studies (Borenstein et al., 2009; Rosenthal & DiMatteo, 2001; Schmidt, Oh, & Hayes, 2009). Comparing to a Fixed-Effects (FE) models solution, the RE models have other statistical and theoretical advantages, as they model variability from both between- and within-studies producing larger standard errors and confidence intervals. Although FE models are more powerful in detecting significant effects, RE models are more conservative concerning the statistical significance, and thus reducing the risk of type I errors.

Mixed-effect model for moderation analysis. In order to examine categorical moderators, we used a mixed-effect model (Borenstein, Hedges, Higgins, & Rothstein, 2011). This procedure uses RE model to compute the mean effect size for each level of the moderator (i.e., categories), and the FE model to analyze the homogeneity of the overall effect across studies and moderators levels. A first step was to determine if there was a systematic variation across effect sizes by computing the heterogeneity statistic Qw, which, in the case of a significant result, suggest the presence of moderating variables (Cooper, 1998). The Qw statistic tests the within-sample homogeneity by fitting the proportion of variation across effect sizes relative to the expected variance (by sampling error alone) against a chi-squared distribution with $k - 1$ degrees of freedom, where k represents the number of independent effect sizes within-class (Hedges & Olkin, 1985). The Qb statistic was calculated to examine the heterogeneity across levels of the moderator, and is based in a similar procedure as the Qw, which instead analyses whether between-class variance differs from the expected variance of sampling error. This meta-analytic procedure is analogue to a one-way between-

subjects analysis of variance (ANOVA). In the case of significant Qb statistics, we performed post hoc contrasts between each pair of categories that were relevant to the review.

Limited number of effect sizes. According to Hedges and Vevea (1998), five effect sizes is the minimum to have a stable RE test. However, in the present review, we found that many of the categories (i.e., levels) of the moderators had 4 and 5. Thus, in categorical moderator analysis we excluded those with less than 4 independent effect-sizes in order to address important hypothesis. While, we have to be careful in interpreting the effect sizes in those cases, pointing with more relevance its magnitude.

Continuous moderators. A meta-regression procedure was used for continuous moderators, which is based in a weighted least-squares regression model (Borenstein et al., 2009; Hedges & Olkin, 1985).

Software. The mentioned meta-analytic procedures were performed as implemented by Borenstein et al. (2009) in the Comprehensive Meta-analysis 2.0 software (CMA, Biostat, Inc, New Jersey, USA).

Results

Characteristics of the Studies and Outliers

Of the 78 papers used in this meta-analytic study, 63 papers offered 128 studies able to be included in the principal meta-analysis of familiarity/fluency effects in duration judgments. *Appendix* summarizes the main characteristics of studies that contributed to the principal meta-analysis, and the remaining studies included in further analysis (i.e., repetition - "Rep": R0, R1, R2 codes).

Data set was first screened for the occurrence of outliers, in order to fit to the normality assumption of the moderation tests (Borenstein et al., 2011). Two studies having effect sizes larger than 4 *SDs* from the mean were removed from moderator analysis (e.g., Bar-Haim et al., 2007; Pool et al., 2015).

Primary Meta-Analysis

General Fluency Effect. The primary meta-analysis (k = 128, n = 3,338) revealed a significant general processing fluency/familiarity effect across studies, showing that more

fluent/familiar stimuli are judged to be longer than less fluent/unfamiliar stimuli (Hedges' g = .522, confidence interval [CI] = .419−.624, Z = 9.99, $p < .001$). The magnitude of this general effect is highly variable across different studies (Q_w = 831.13, $p < .001$, I^2 = 84.72), suggesting it is probably moderated by other factors. This variability supports our exploratory and theoretical guided analysis of possible moderator variables.

Publication Bias. In order to analyze the publication bias of the effect at study, we drew the *funnel plot* graphic (i.e., individual studies' effect size as a function of its precision, 1/Standard Error). A visual inspection of this funnel plot revealed a slight asymmetry (see *Figure 3*) suggesting a lack of studies with low precision reporting negative effects. The *Egger's test* that addresses potential bias of published studies with small samples (Egger, Smith, & Altman, 2001), was shown to be significant, $t(126) = 3.927$, $p < .001$. Even with the *trim-and-fill* correction method developed by Duval and Tweedie (2000), whereas 23 hypothetical studies were ascribed and the general effect across studies was reduced, the results persisted to be significant (Hedges' g = .318, CI = .207−.428). The *Fail-Safe N test* (Rosenthal, 1979) reveal that an implausible number of 7,667 hypothetical studies with null effect have to be added to the meta-analysis in order for the difference across studies become statistically non-significant ($p > .05$).

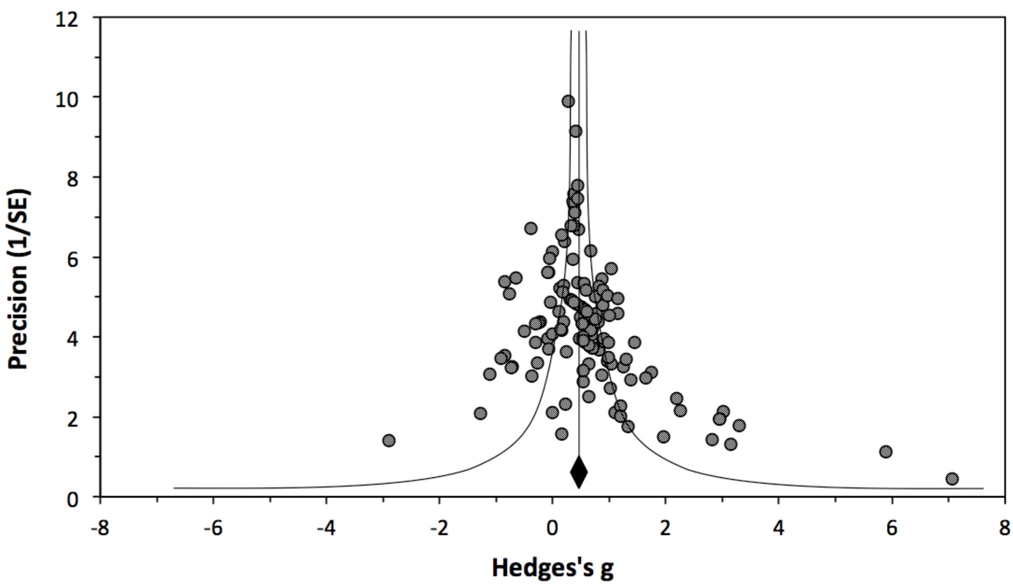

Figure 3. Funnel plot of precision for the effect using the random-effect model.

Declining Effect. A meta-regression analysis with publication-year as a continuous predictor of general familiarity/fluency effect size allow us to test for declining of the

detection of the effect over time (Schooler, 2011; Francis, 2012). The plot of interaction (see *Figure 4*) denotes a slight slope in the weighed effect size of general fluency over publication-year (1964−2016). Indeed, this drop in Hedges' *g* indicates a significant declining effect ($B_{intercept}$ = 26.55, β_{year} = −. 013, *SE* = .004, *Z* = −3.68, *p* < .001). However, the proportion of total between-study variance explained by publication-year is approximately zero ($\tau_{increment}^2$ = .002, R^2 = .00), which could indicate that the test of the impact of specific moderators over the years has changed and could be responsible for some proportion of the variance. Indeed, when we restricted the analysis to the years 1985-2016 (when the studies become more theoretically oriented and testing a more variety of fluency manipulations), the publication-year coefficient become non-significant (*k* = 90, $B_{intercept}$ = 16.66, β_{year} = −. 008, *SE* = .005, *Z* = −1.56, *p* = .118).

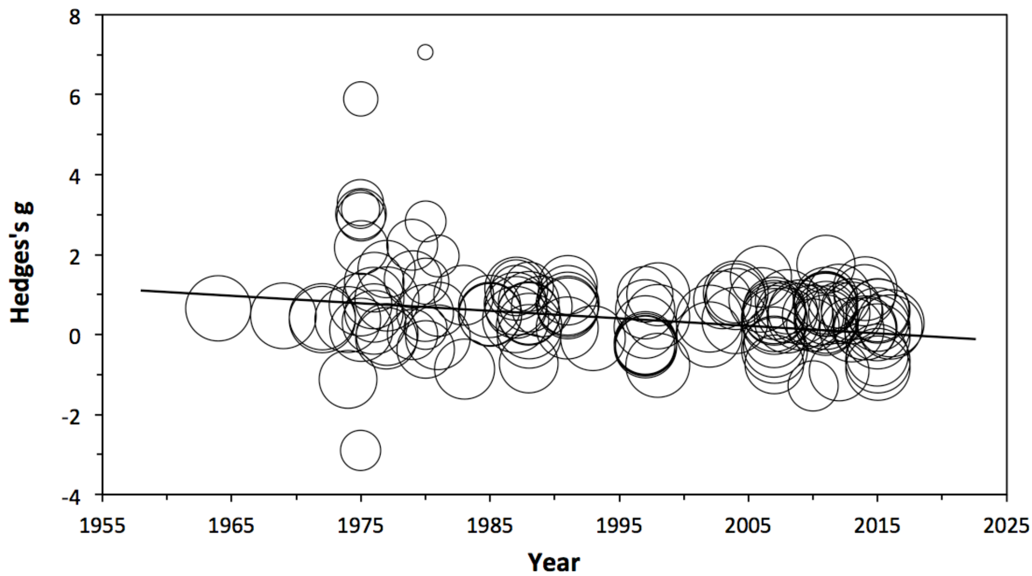

Figure 4. The plot portrays the negative change in general processing fluency effect sizes as a function of time (i.e., years). The size of the circles indicates the relative contribution (random weight) of each study to the analysis.

Distinguishing conceptual and perceptual fluency components of the effect

*Conceptual and perceptual fluency main effects***.** The separated combined effect sizes of conceptual fluency (*k* = 50, *n* = 1,519, Hedges' *g* = .517) and of perceptual fluency (*k* = 85, *n* = 2,009, Hedges' *g* = .514) are both significant (*see Table 3*). As we expected the effects of both components did not differ, in such that their impact in duration judgments is similar (Q_B = .001, *p* = .980). Although one can admit an almost identical effect, different within-group

homogeneity values between perceptual fluency studies (Q_w = 682.50, p < .001, I^2 = 87.69) and conceptual fluency studies (Q_w = 206.62, p < .001, I^2 = 76.28), suggest that variation in sub-classes of fluency manipulation could differ between these components. We run separate analysis for each in order to understand these results.

Table 3. Meta-analytic results of general fluency effects

Moderator	k	g	95% CI	Qw	Q_B	p
General processing (fluency)	128	0.52 ****	0.42 , 0.62	831.13 ****		
Processin (fluency) components						
Conceptual	50	0.52 ****	0.40 , 0.64	206.62 ****	0.00	.98
Perceptual	85	0.51 ****	0.37 , 0.66	682.50 ****		
Conceptual (fluency) manipulation						
Frequency in language	14	0.50 ****	0.33 , 0.68	31.41 **	6.46	.17
Words vs. non-words	13	0.80 ****	0.55 , 1.05	54.15 ****		
Previous knowledge	12	0.47 **	0.14 , 0.81	85.09 ****		
Previous exposure	13	0.44 ****	0.24 , 0.64	38.34 ***		
Conceptual priming	3	0.70 ****	0.41 , 0.98	0.49		
Perceptual (fluency) manipulation						
Repetition priming	10	-0.51 ***	-0.77 , -0.24	33.98 ***	98.24	< .0001
Complexity	20	0.14	-0.15 , 0.43	131.96 ****		
Contrast	25	1.35 ****	1.01 , 1.69	183.00 ****		
Size	25	0.72 ****	0.52 , 0.91	87.20 ****		
Time coherence	10	0.38 ***	0.15 , 0.61	36.44 ****		
Word length and letter case	6	-0.49	-1.06 , 0.09	52.11 ****		
Stimulus type						
Semantic	51	0.66 ****	0.48 , 0.83	352.32 ****	3.98	< .05
Non-semantic	77	0.44 ****	0.31 , 0.56	465.99 ****		

* p < .05. ** p < .01. *** p < .001 **** p < .0001

*Conceptual fluency manipulations***.** The test of the between-manipulations homogeneity revealed that different manipulations of conceptual fluency did not promote effects with different magnitudes (Q_B = 6.456, p = .168; *see Table 3*). Hedges' g varied between .438 when the manipulation was a familiarization task run before the experiment (i.e., previous exposure) and .801 when the manipulation was the presentation of words (familiar stimuli) vs non-words (unfamiliar stimuli). Post-hoc analysis suggest that the use of words vs. non-words as a manipulation of familiarity yielded a larger effect size compared to

all other types of conceptual manipulation pooled together (Hedges' g = .477, CI = .348–.606, Q_B = 5.017, p = .025).

Perceptual fluency manipulations. The test of the between-manipulations of homogeneity clear suggests a discrepancy of the effects promoted by each manipulation (Q_B = 98.24, p < .001; *see Table 3*). Stimuli complexity had no effect at all (Z = .942; p = .346). Positive (large) effect sizes were found for foreground-background-contrast and physical-size contrasts, and negative (medium) effect sizes were found for manipulation of word-length/letter-case and repetition-priming. Negative effects of word-length/letter-case are possibly related to the recoding to physical size (see stimuli size effects bellow) and we expected negative effect of repetition-priming, given being an intra-trial repetition manipulation (see repetition effects below). Follow-up comparisons showed that foreground-background-contrast yield a larger effect size compared with physical-size (Q_B = 10.242, p < .001) and the latter compared with time-coherence (Q_B = 4.871, p = .027).

Testing internal-clock model predictors

Limit capacity index (single versus multiple judgments). We first tested if the familiarity/fluency duration effect was different in studies that ask participants only duration estimation or ask also other judgments. No difference was found, Q_B = 1.478, p = .478 (*see Table 4*) when all the studies were considered. However, when considering only perceptual fluency studies, the analysis shown a significant difference in the effect sizes found in single judgment (Hedges' g = .593) and in multiple judgments (Hedges' g = .288) conditions, Q_B = 4.273, p = .039. Such differences were not observed in conceptual fluency studies, Q_B = .138, p = .710 (single: Hedges' g = .498; multiple: Hedges' g = .544).

*Selective attention (duration x fluency interaction)***.** This analysis allowed us to test if familiarity effects are a constant added to real time or are incremented with time duration. The results suggest the second to be true; revealing that the weighted mean effect size of the within-study interaction between fluency and duration was positive and significant (*see Table 4*). First analysis suggests this to be an effect with a small effect size (Hedges' g = .267), but analysis after withdrawing the studies that had unreported statistics and were represented by a p = .50, suggests the effect is higher (Hedges' g = .416). The same pattern of results was found for conceptual and perceptual fluency studies (Q_B = .432, p = .511 or without

Table 4. Meta-analytic results of internal-clock model predictors of processing efficiency effects

	Overall processing (fluency)					Conceptual (fluency) / familiarity					Perceptual (fluency)					Conceptual vs. perceptual (fluency)	
Moderator	*k*	*g*	95% CI	Q_B^a	*p*	*k*	*g*	95% CI	Q_B^a	*p*	*k*	*g*	95% CI	Q_B^a	*p*	Q_B^b	*p*
Limited capacity indexes																	
Multiple judgments																	
Duration only	94	0.57 ****	0.43 , 0.70	1.48	.23	30	0.50 ****	0.34 , 0.66	0.14	.71	68	0.59 ****	0.41 , 0.78	4.27	< .05	0.58	.45
Plus other judgments	34	0.44 ****	0.29 , 0.59			20	0.54 ****	0.36 , 0.73			17	0.29 *	0.06 , 0.51	2.520	< .05	3.05	.08
Selective attention indexes																	
Duration x Fluency	37	0.42 ****	0.26 , 0.57			9	0.55 **	0.16 , 0.94			28	0.38 ****	0.21 , 0.55			0.64	.42
(D x F) x Duration range																	
≤100	13	0.38 *	0.00 , 0.75	1.28	.53	4	0.33	-0.34 , 1.01	1.44	.23	9	0.41	-0.07 , 0.89	0.05	.97	0.03	.86
≤1000	16	0.38 ****	0.19 , 0.57			–	–	– –			15	0.39 ***	0.19 , 0.59			–	–
>1000	8	0.60 ****	0.26 , 0.94			4	0.86 **	0.32 , 1.41			4	0.34	-0.05 , 0.74			2.30	.13
(D x F) x Duration difference																	
≤100	23	0.30 **	0.07 , 0.52	3.22	.07	4	0.33	-0.34 , 1.01	0.84	.36	19	0.30 *	0.06 , 0.54	1.82	.18	0.01	.93
>100	14	0.57 ****	0.37 , 0.76			5	0.71 **	0.27 , 1.16			9	0.52 ****	0.31 , 0.73			0.59	.44
(D x F) x Trials																	
≤100	18	0.47 ****	0.28 , 0.66	0.40	.53	5	0.71 **	0.27 , 1.16	0.84	.36	13	0.39 ***	0.18 , 0.61	0.00	.97	1.58	.21
>100	19	0.37 **	0.12 , 0.62			4	0.33	-0.34 , 1.01			15	0.39 **	0.12 , 0.66			0.02	.88
Other moderators																	
Temporal tasks (measures)																	
Estimation	69	0.49 ****	0.36 , 0.62	2.40	.49	36	0.58 ****	0.45 , 0.72	8.58	< .05	40	0.36 ***	0.15 , 0.57	5.93	.05	3.13	< .01
Discrimination	43	0.61 ****	0.41 , 0.82			9	0.18	-0.08 , 0.45			34	0.76 ****	0.50 , 1.02			9.22	.08
Reproduction	10	0.35 *	0.03 , 0.68			–	–	– –			9	0.40 *	0.05 , 0.75			–	–
Production	6	0.66 **	0.24 , 1.08			4	0.80 ***	0.37 , 1.23			–	–	– –			–	–
Stimulus modality																	
Auditory	15	0.51 ****	0.24 , 0.77	0.01	.92	8	0.55 *	0.10 , 1.01	0.03	.87	7	0.47 **	0.14 , 0.80	0.08	.78	0.09	.77
Visual	113	0.52 ****	0.41 , 0.64			42	0.51 ****	0.39 , 0.64			78	0.52 ****	0.36 , 0.68			0.01	.94

Note. Dashes indicate k < 3 (sub-categories with k < 3 studies were not submitted to meta-analysis)

[a] Q_B for comparasion between sub-categories of a given moderator. [b] Q_B for comparasion between conceptual and perceptual fluency.

* $p < .05$. ** $p < .01$. *** $p < .001$ **** $p < .0001$

unreported statistics Q_B = .610, p = .423). The within duration x fluency overall effect was independent of duration range (Q_B = 1.280, p = .527), mean duration difference (Q_B = 3.220, p = .07), number of trials (Q_B = 0.40, p = .53) and stimuli by trial (Q_B = 0.00, p = .97). The effect did hold up for both types of fluency, and did not differ in any level of these moderators when comparisons were made between conceptual and perceptual fluency studies.

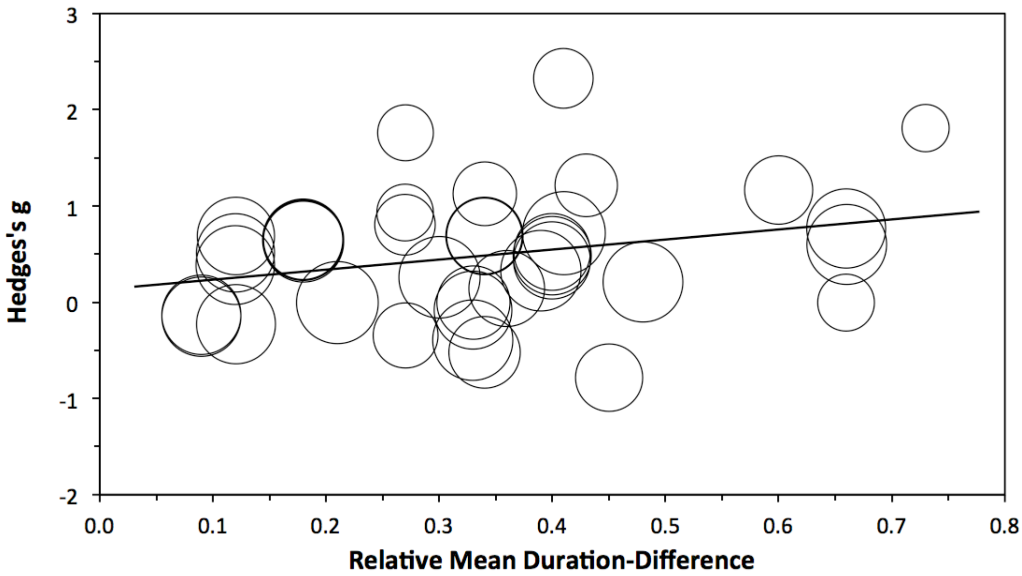

Figure 5. The plot portrays the positive change in duration x fluency interaction effect sizes as a function of relative mean duration-difference (i.e., temporal judgment difficulty). The size of the circles indicates the relative contribution (random weight) of each study to the analysis.

Type of stimuli. Because semantic processing is expected to occur later in time, we also expected familiarity effects to be stronger with this material. We therefore examined whether the effect of familiarity/fluency on duration judgments differed depending on whether the stimuli was non-semantic (i.e., perceptual) or semantic (i.e., conceptual). As expected there was a significant effect of stimulus type, Q_B = 3.978, p = .046, indicating that the semantic condition yielded larger effect sizes compared with the non-semantic condition (*see Table 3*). Separate analysis for conceptual and perceptual fluency manipulations find similar patterns of results with no difference between the two type of manipulations.

Testing the fluency-attribution model predictors

Discrepancy (contextual distribution of stimuli) assumption

Within versus between-subjects designs. Because a direct comparison between within and between-subjects designs in meta-analysis have multiple caveats (Dunlap et al., 1996; Morris & DeShon, 2002), we carried out separate analysis for each set of studies, expecting familiarity/fluency effects to be stronger in within-subjects setting (heterogeneous presentation) than in between-subject setting (homogenous presentation). In line with such predictions studies that used homogenous presentation. Context had a null effect size (Hedge's g = .075; Z = .252; p = .801), with studies with heterogeneous presentation context yielding a significant effect-size (Hedge's g = .540; Z = 10.166; p < .001). We performed further separate analysis of conceptual and perceptual fluency studies because less than 3 studies manipulated conceptual fluency between subjects. Analysis of isolated perceptual fluency studies showed both to have a similar pattern of results (*see Table 5*

*Levels of fluency***.** We tested if relative experiential fluency would moderate the effect size of general processing fluency by comparing studies using only two levels of fluency (i.e., low versus high fluency) with studies using more than two levels (i.e., increasing levels of fluency). The between-group homogeneity test revealed that two-levels of fluency condition yielded smaller effect sizes, Q_B = 5.241, p = .022 (*see Table 5*). However, this difference was only observed in the perceptual fluency studies, Q_B = 12.290, p < .001 (two levels: Hedges' g = .316; multiple levels: Hedges' g = .881). The effect is not only non-significant in the conceptual fluency studies, Q_B = .762, p = .383 (two levels: Hedges' g = .552; multiple levels: Hedges' g = .379), but also tends to go in the opposite direction. The significant differences between conceptual and perceptual fluency in each moderator level (i.e., two levels, Q_B = 4.729, p = .030, and more than two levels of fluency, Q_B = 5.406, p = .020), suggests an interaction between levels of fluency and fluency type

Number of trials. The discrepancy hypothesis views the number of trials as a possible moderator of the experience of fluency and so its impact on duration. Higher number of trials in turn makes differences in fluency to be more expected, decreasing the effect. Analysis corroborates this hypothesis showing that the effect sizes of general processing fluency were qualified by the number of trials, Q_B = 7.305, p < .01 (*see Table 5*), defined by two categories (i.e., less and more than 100 trials). But this moderation was only observed in perceptual fluency manipulations, where analysis suggests that when more trials are used in the experiment the effect size tends to decrease, , Q_B = 11.571, p < .001 (under 100 trials: Hedges' g = .817; above 100 trials: Hedges' g = .296). The effect size was independent of

Table 5. Meta-analytic results of fluency-attribution model predictors of fluency effects

	Overall processing (fluency)					Conceptual (fluency) / familiarity					Perceptual (fluency)					Conceptual vs. perceptual (fluency)	
Moderator	*k*	*g*	95% CI	Q_B^a	*p*	*k*	*g*	95% CI	Q_B^a	*p*	*k*	*g*	95% CI	Q_B^a	*p*	Q_B^b	*p*
Contextual indexes																	
Heterogeneity																	
Between	6	0.08	-0.51 , 0.66	–	–	–	–	– –	–	–	4	-0.03	-1.05 , 0.99	–	–	–	–
Within	122	0.54 ****	0.44 , 0.64			48	0.53 ****	0.40 , 0.65			81	0.54 ****	0.39 , 0.69			0.01	.94
Levels of fluency																	
Two	82	0.44 ****	0.33 , 0.56	5.24	< .05	37	0.55 ****	0.43 , 0.67	0.76	.38	51	0.32 ***	0.14 , 0.49	12.29	< .001	4.73	< .05
More than two	46	0.72 ****	0.51 , 0.92			12	0.38 *	0.01 , 0.75			34	0.88 ****	0.62 , 1.14			5.41	< .05
Trials (number)																	
≤100	64	0.67 ****	0.52 , 0.82	8.08	< .01	29	0.51 ****	0.36 , 0.67	0.00	.95	37	0.82 ****	0.57 , 1.06	11.57	< .001	4.23	< .05
>100	64	0.38 ****	0.25 , 0.51			21	0.52 ****	0.33 , 0.72			48	0.30 ***	0.12 , 0.47			2.85	.09
Temporal ambiguity indexes																	
Mean difference between durations																	
=0	28	0.90 ****	0.59 , 1.21	14.37	< .001	10	0.62 ****	0.43 , 0.81	11.25	< .01	20	1.05 ****	0.60 , 1.50	8.58	< .05	2.96	.09
≤100	57	0.57 ****	0.44 , 0.70			23	0.67 ****	0.55 , 0.80			38	0.48 ****	0.26 , 0.69			2.39	.12
>100	43	0.31 ****	0.16 , 0.45			17	0.23 *	0.00 , 0.46			27	0.33 ***	0.15 , 0.51			0.44	.51
Fluency source awareness indexes																	
Type of judgment																	
Duration only	94	0.57 ****	0.43 , 0.70	1.48	.48	30	0.50 ****	0.34 , 0.66	2.06	.36	68	0.59 ****	0.41 , 0.78	5.43	< .05	0.58	.45
Irrelevant dimension	24	0.44 ****	0.26 , 0.61			12	0.64 ****	0.46 , 0.82			15	0.23	-0.01 , 0.47			6.93	< .01
Relevant dimension	10	0.46 ***	0.17 , 0.74			8	0.40 *	0.07 , 0.73			–	–	– –			–	–
Duration range																	
≤100	46	0.90 ****	0.67 , 1.13	17.68	< .001	20	0.63 ****	0.49 , 0.77	2.92	.23	29	1.12 ****	0.68 , 1.57	12.71	< .01	4.28	< .05
≤1000	58	0.39 ****	0.27 , 0.52			18	0.46 ****	0.25 , 0.66			43	0.38 ****	0.22 , 0.53			0.38	.54
>1000	24	0.31 **	0.10 , 0.51			12	0.41 **	0.11 , 0.71			13	0.17	-0.12 , 0.46			1.30	.25

Note. Dashes indicate k < 3 (sub-categories with k < 3 studies were not submitted to meta-analysis) or the impossibility to calculate Q_B statistic

[a] Q_B for comparasion between sub-categories of a given moderator. [b] Q_B for comparasion between conceptual and perceptual fluency.

* $p < .05$. ** $p < .01$. *** $p < .001$ **** $p < .0001$

number of trials in conceptual fluency manipulations, Q_B = .004, p = .948 (under 100 trials: Hedges' g = .514; above 100 trials: Hedges' g = .523).

Temporal ambiguity

*Mean difference between duration***.** We address as a proxy of ambiguity/difficulty of processing time information the actual duration differences used within each experiment session. We examine if the mean difference between durations (used within temporal-task) moderates the familiarity/fluency duration effect. The analysis yielded a significant moderating effect, Q_B = 14.366, p < .001, suggesting that the effect sizes differed across the three categories of mean duration-difference (*see Table 5*). Corroborating the theoretical hypothesis, the pattern of results indicates that, as mean duration-difference decreased, the effect size of fluency increased. The effect sizes were larger for zero than for under 100 ms mean duration-differences, Q_B = 3.627, p = .056, and larger for under 100 ms than for above 100 ms mean duration-differences, Q_B = 6.948, p < .01. The linear decrease of the effect is less clear when conceptual and perceptual fluency are separated in the analysis. For conceptual fluency manipulations the first two levels promote similar effect sizes (for zero: Hedges' g = .622; and < 100 ms: Hedges' g = .671; mean duration-differences: Q_B = .179, p = .672) having only mean duration-differences above 100 ms a smaller effect-size (Hedges' g = .231) that diverged significantly from others (Q_B = 12.019, p < .001). By contrast, under perceptual fluency contexts the two first levels differ in such that effect-sizes were larger for zero mean duration differences (Hedges' g = 1.052) than for under100 ms (Hedges' g = .477; Q_B = 7.094, p < .01), being this last one similar to effects sizes found above 100 ms (Hedges' g = .330; Q_B = 1.062, p = .303).

*Standardized mean difference between durations***.** Additionally, because temporal judgment difficulty could be dependent of duration magnitude as theorized by Weber's Law (i.e., differences in magnitude are harder to discriminate in function of magnitude), we examined the mentioned moderation effect controlling for mean duration used within-study. We did that by creating an index, which is the mean duration-difference divided by mean duration, and tested it as a continuous predictor of fluency effect size in a meta-regression procedure. The prediction was significant, Q_R = 6.500, p = .011, revealing that fluency effect size decreased as relative mean duration-difference increased, $B_{intercept}$ = .707, β_{year} = –.638, SE = .250 (*see Figure 5*), which sustained the former results using absolute duration-differences.

The impact of conceptual vs. perceptual fluency manipulations was analyzed by introducing it as a covariate in the meta-regression model. No difference between the two manipulations seem to occur since similar negative trends were observed, Q_R = 8.290, p = .016. In fact similar negative trends were observed separately for conceptual fluency, Q_R = 4.680, p = .031, $B_{intercept}$ = .725, β_{year} = −.703, SE = .325, and perceptual fluency manipulations, Q_R = 6.820, p < .01, $B_{intercept}$ = .765, β_{year} = −1.009, SE = .386.

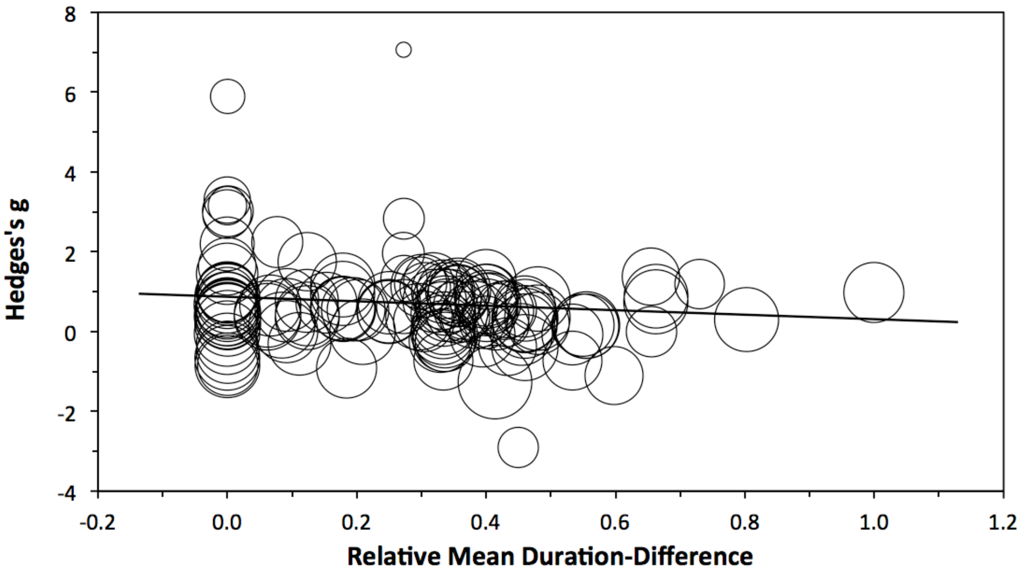

Figure 6. The plot portrays the negative change in general processing fluency effect sizes as a function of relative mean duration-difference (i.e., temporal judgment difficulty). The size of the circles indicates the relative contribution (random weight) of each study to the analysis.

***Discounting hypothesis (fluency source awareness*)**

*Relevance of dimension judgment***.** The type of judgments requested from participants is likely to create conditions that favor fluency source awareness. We test if the presence of other judgment in the setting besides duration promoted discounting effects, by comparing studies without extra non-temporal judgments with those with those judgments. The presence of these judgments did not qualify the magnitude of familiarity duration effect, Q_B = 1.478, p = .478 (*see Table 6*). Follow-up comparisons indicated that effect sizes of studies with single duration judgments (i.e., without concurrent evaluations of non-temporal dimensions of the stimulus) were comparable with those in studies where additional judgments were either

irrelevant (Q_B = 1.327, p = .249) or relevant (Q_B = 0.018, p = .893) to fluency manipulations. The same pattern of results is detected with when we consider only conceptual fluency studies Q_B = 2.06, p = .36. However, the same did not occur for studies that manipulated perceptual fluency, Q_B = 5.426, p = .020; although the insufficient number of studies in this sub-analysis did not allow us to control the analysis for level of relevance. Significant differences between conceptual and perceptual fluency were found for the irrelevant dimension, Q_B = 6.928, $p <$ .01, but not for studies with only duration judgments, Q_B = 0.577, p = .447.

*Duration range***.** The actual duration of the stimuli was hypothesized to be likely to provide conditions that favor discounting effects. Results show that physical durations used within individual studies moderate the familiarity/fluency effects (Q_B = 17.678, p < .001; *see Table 5*). Familiarity/fluency effects were larger when duration judgments were made under the millisecond range (i.e., < 100 ms) than those made in the hundred-millisecond range (Q_B = 14.684, p < .001) or above 1,000 ms (Q_B = 14.357, p < .001). These two last ranges had comparable effect sizes (Q_B = .477, p = .490). However this overall pattern was only verified in perceptual fluency studies (Hedges' g = 1.124, .378, and .166 respectively, Q_B = 12.707, p < .001); no significant differences between duration ranges was found in conceptual fluency studies (Hedges' g = .632, .458, and .411 respectively, Q_B = 2.922, p = .231). Although no differences were found between conceptual and perceptual fluency manipulations with regard to the under 100ms range, there is a significant difference in conceptual and perceptual fluency impact duration over 100msec range (see *Table 5*).

Repetition

A set of additional 34 studies (from 15 articles, n = 850) which were not included in previous analysis of familiarity/fluency effects were added to the analysis presented below, aiming to test the effects of intra-trial repetition in duration judgments were entered in this analysis (*see Appendix B*).

Repetition type (delay) Here we test the hypothesis that intra-experiment repetition promotes different effects (negative) compared to repetition of stimuli previous to experiment (as a manipulation of familiarity). As expected the analysis revealed a moderating effect of repetition type (Q_B = 149.413, p < .001), indicating that intra-experiment repetition promotes in fact an effect that is different from the familiarity/fluency one (*see Table 6*). Analysis comparing the two types of intra-experiment repetition (inter-trial and intra-trial), show that

both exhibit medium negative effect sizes, with no differences between them (Q_B = .992, p = .319).

Table 6. Meta-analytic results of repetition effects in duration judgments

Moderator	k	g	95% CI	Qw	Q_B	p
Repetion type (delay)						
Previous to experiment	56	0.54 ****	0.42 , 0.66	260.82 ****	149.41	< .0001
Inter-trials	6	-0.48 ****	-0.68 , -0.28	6.29		
Intra-trials	38	-0.61 ****	-0.77 , -0.45	182.94 ****		

* $p < .05$. ** $p < .01$. *** $p < .001$ **** $p < .0001$

Other moderators.

We tested for additional methodological features of the studies that could impact the effect size of the familiarity/fluency effect on duration.

Measure (temporal tasks). Although the measuring method used to judge duration did not moderated the effect size (Q_B = 2.539, p = .468; *see Table 4*), studies that used the reproduction task did showed apparently smaller effect size (Hedge's g = .354; Z = 2.115; p = .034). Pair comparisons revealed no significant differences between temporal tasks effect sizes (all p > .188).

Stimulus modality. Stimulus modality (i.e., visual versus auditory) did not qualify fluency effect sizes, Q_B = .011, p = .918 (*see Table 4*). No differences were found either in conceptual or perceptual fluency studies.

Discussion

This meta-analysis of the familiarity effect is the first to consider, in a side-by-side manner, attentional and fluency mechanisms underlying duration judgments. The main goal of the present meta-analysis was to clarify if duration of familiar and fluency stimuli is judged to be longer compared with unfamiliar stimuli and to examine the boundary conditions of this effect. We specifically have focused moderators that index the processes that both the dedicated information-processing model of time perception and the generic attribution-

fluency model of judgment offer to explain the effect. We address these questions by contextualizing the effects promoted independently by familiarity (conceptual fluency) manipulations from those promoted by perceptual fluency manipulations.

The results indicate that the familiarity effect is reliable. Across studies there is a significant familiarity temporal overestimation effect of medium size: Hedges's g = .52 (Cohen, 1988). As expected the effect occurs for both familiarity (conceptual) and perceptual manipulations of non-temporal features of the stimuli, both having a similar magnitude. However, in this meta-analytical review it is clear that the two types of manipulations are not acting in exactly the same way on our perception of time. We will summarize this analysis after testing our main assumptions below.

Meaningfully, both familiarity (conceptual) and perceptual manipulations of non-temporal features show effect sizes with a high degree of heterogeneity, suggesting that, as expected, the effect significantly varies under a set of conditions. We focus on a set of these possible moderators by defining the characteristics that are relevant for the considered theoretical accounts: dedicated information-processing model of time perception and the generic attribution-fluency model of judgment. We review below the results relevant for each theoretical account, showing that this meta-analysis allows us to identify a sub-set of moderators that have the potential to shed new light on how familiarity and perceptive features impacts on duration judgments.

Attention account (internal-clock models of time perception)

Overall the results offer controversial conclusions to the dominant conception of attention explanation of familiarity effects in duration judgments as an effect of processing efficiency (Chastain & Ferraro, 1997; Hochhaus et al., 1991; Warm & McCray, 1969) at least for the duration range here in analysis. The detection of the effect itself suggest that it is likely that attention impacts the initial counting of the internal clock (e.g., Lejeune, 1998) although no extra evidence supports this assumption. Two relevant results were made clear here. Firstly, as it has been proposed within an attention approach, familiarity/fluency effects occur as a function of actual physical duration ("*slope effects*") suggesting that the effect is dependent on a late attention processes related with sustained (selective) attention. Secondly, and perhaps more informative, we found no evidence that the effect is dependent of explicit distribution of attention resources allocated between temporal and non-temporal features of

the stimulus. Our analysis does not show evidence that familiarity or perceptual fluency increases processing efficiency by releasing the attentional and executive control resources needed for sustained attention (Posner, Snyder, & Davidson, 1980; Shiffrin & Schneider, 1977). We discuss these two aspects of the results below.

Our analysis of the familiarity/fluency effects in duration judgments by actual physical duration interaction, calculated within-study, allowed us to test if we only have the presence of "*intercept effects*" (based on early selective attention processes) or we find also "*slope effects*" (based on late attention or constant interference processes). Results revealed a "*slope effect*", which is defined by an increase of the familiarity/fluency effect as a function of physical duration used within-study. This suggests the effect to be independent of the latency to close or open the switch according to clock-internal models (Lejeune, 1999; see also Matthwes & Meck, 2016). The effect is not one dependent upon a differential onset detection of the stimulus to be timed, (see Enns, Brehaut, & Shore, 1999; Mattes & Ulrich, 1998; Seifried & Ulrich, 2011) but one dependent upon what is brought about by continuing attending to the stimulus. This challenges the idea that familiarity/fluency effects occur because their properties attract exogenous attention (e.g., Montani, Facoetti, & Zorzi, 2014; Althoff & Cohen, 1999; Hsiao & Cottrell, 2008; White, 2008), facilitating the initial detection of the stimulus. Within an attentional account the "*slope effect*" implies that a sustained selective attentional process is interfered with constantly (in different degrees), or at some point late in time, inducing the switch to open (and close) along the interval, and consequently resulting in a progressive loss of temporal units (Zakay & Block, 1997; see also Buhusi & Meck, 2009).

Presumably, familiar/fluent stimuli continuously facilitate the extraction of non-temporal information, initially driven by the mandatory/automatic low-level perceptual processes (Deacon & Shelley-Tremblay, 2000; Palermo & Rhodes, 2007) but allowing latterly the interference of the activation of conceptual structures of knowledge, (e.g., Friederici, 2002; Hagoort, 2008). This led us to hypothesize that "*slope effects*" could be differently detected when conceptual processes were required. Data did not corroborate this hypothesis, suggesting only that at long duration ranges conceptual conditions ($g = 0.86$) showed tendentiously larger "slope effects" than perceptual conditions ($g = 0.34$). Future studies may address this issue trying to understand how the time course of processing the non-temporal stimulus features either being perceptual or conceptual features interferes with sustained attention mechanisms directed towards time.

But "*slope effects*" may occur for other reasons than interferences during sustained attention processes; namely because there could be an acceleration of pacemaker rate (e.g., Penney, Gibbon, & Meck, 2000; Wearden Edwards, Fakhri, & Percival, 1998). This type of acceleration is expected to occur mostly because of arousal (Droit-Volet & Meck, 2007). Stimuli able to promote physiological activation, induce a progressive increase of accumulation of time units (Lejeune, 1999; see also Matthews & Meck, 2016). Thus if we assume familiarity or perceptual fluency to increase arousal this can be an explanation for the "slope effect". But although fluency and familiarity have been shown to be affectively charged (Garcia-Marques & Mackie, 2000; Winkielman & Cacioppo, 2001) a slightly diffused affective state has been associated with low arousal. But of course that this is still a hypothesis to be further and better explored.

But if the conclusions regarding the "*slope effects*" are able to be addressed by the attentional approach it is harder for it to help us understand why we found no evidence that the effect is also dependent on the explicit distribution of attention resources allocated between temporal and non-temporal features of the stimulus. There is no impact of divided attention in the familiarity/fluency duration effect. The effect is of comparable size when duration's judgments were made in single (i.e., duration only) and in multiple judgments conditions, suggesting that familiarity/fluency does not increase resistance to the interference possible promoted by the concurrent judgment.

One reason why we may fail to understand the relevance of divided attention is because of the short duration range we are focusing in the analysis. Overall, the median of stimulus duration across the studies included in this meta-analysis is 0.18 s. Several findings suggest that controlled processes (including divided allocation of attention) have little impact in duration judgments when stimulus duration is at millisecond range (e.g., Hellström & Rammsayer, 2004; Rammsayer & Lima, 1991; Rammsayer & Ulrich, 2011). If so, the familiarity/fluency duration effect found in these durations may be less prone to be explained by the attentional account (see also Block et al., 2010, for the possibility of null effects even within larger durations). This if more relevant when we consider that the magnitude of the familiarity/fluency effect in the present meta-analysis was higher for the short duration range (i.e., millisecond) as compared with sub- and supra-second ranges. It is thus possible that the duration processing on a millisecond range involves other distinct temporal mechanisms not mediated by the attentional controlled cognitive processes (see Buonomano, Bramen, & Khodadadifar, 2009; Lewis & Miall, 2003a, 2003b, 2009; Fraisse, 1984; Grondin, 2010;

Penney & Vaitilingam, 2008). It should be noticed that for perceptual fluency manipulations the analysis even suggests effects in the opposite direction that would be expected (see below the comments of the analysis on multiple judgments). Overall, this data suggests that the attention-limited capacity account may not be able to explain the familiarity duration effects detected at reduced ranges of durations. Thus as some authors working with the framework of internal-clock models have suggested, non-temporal proprieties influences in duration judgments of these durations may better be explained as a "decision bias" (e.g., Cai & Wang, 2014; Rammsayer & Verner, 2015)

Attribution-fluency account

Overall data is quite consistent with what should be expected based on the theoretical assumption that familiarity effects in duration judgments depend on the metacognitive attribution of processing fluency (e.g., Kleider & Goldinger, 2004; Reber et al., 2004; Witherspoon & Allan, 1985). Both conceptual/familiarity and perceptual fluency impact similarly duration judgments, as would be expected if these features promote meta-cognitive experiences able to inform/bias decision or judgments about duration.

In our review of the metacognitive approach we analyze a set of assumptions of different fluency models that would be able to moderate the effects. Namely we derived moderators from the fluency informational assumption (Novemsky et al., 2007; Schwarz , 2011) the discrepancy hypothesis (Whittlesea & Leboe, 2003) and the fluency-attribution assumption (Bornstein & D'Agostino, 1992).

Our findings suggest that both type of fluency effects in duration judgments occur when temporal-information is hard to discriminate. This is in line with perspectives that processing feelings offer a type of information that is more relevant when judgments are harder to be make (e.g., Dechêne et al., 2010; Gomez & Robertson, 1979; Novemsky et al., 2007; Unkelbach, 2007). Fluency is thus more likely to be an experience used as a diagnostic cue to disambiguate the relevant information to the judgment at hand. Accordingly, our results show a progressive increase in the effect size induced by processing fluency as the mean difference of durations within-study decreased. Because smaller duration differences are associated with the shortest duration range, and temporal judgment ambiguity/difficulty could be dependent on duration magnitude as theorized by Weber's Law we control for mean

duration used within-study and continue to find the temporal ambiguity/difficulty effect associated with shorter durations..

The assumption that the subjective experience of fluency is a discrepancy lead us to test if the fluency effect is modulated by the way objective levels of fluency are distributed across trials (Dechêne et al., 2010; Hansen & Wänke, 2015; Westerman, 2008; Whittlesea & Leboe, 2003). We tested fluency discrepancy effects with three different moderators (i.e., fluency heterogeneity, number of fluency levels and number of trials) addressing the contextual distribution of stimuli within-studies. The overall results indicate that processing fluency effects were stronger when fluency variability and heterogeneity was higher or fluency expectancy was lower, in accordance with fluency effects in other types of judgments (e.g., Dechêne et al., 2009; Westerman, 2008; for a discussion see Dechêne et al., 2010; Whittlesea & Leboe, 2003). These results replicates other meta-analysis focusing the "*truth effect*" (Dechêne et al., 2010) and the "*mere-exposure effect*" (Bornstein, 1989), and shows that the fluency effect is only found when high fluent stimuli were intermixed with low-fluent stimuli in within-subject designs (heterogeneous condition); no differences in duration judgments were found in the between-subject design (homogenous condition). We also expected a change in fluency-expectation with an increased number of trials, which would impact duration judgments. And as expected we find a decrease of familiarity/fluency effects over duration with increased numbers of trials (e.g., Hansen, Dechêne, & Wänke, 2008; Laham, Alter, & Goodwin, 2009) suggesting that the experience of differences in fluency of processing was reduced over time. However this only occurs for studies that manipulate perceptual fluency, suggesting this manipulation to be more sensitive to these changes in expectations than manipulations of familiarity.

We also found that general processing fluency effect sizes were higher when more levels of fluency were used, which may have increased heterogeneity and variability favoring contextual comparisons (Whittlesea & Leboe, 2003). However this effect is also not the same for both manipulations of fluency. The "more levels of fluency" effect is only found for perceptual fluency manipulations with no impact at all for familiarity manipulations.

In trying to understand these effects and the dissociation found between perceptual and conceptual differences, we should take into account two phenomena. One is that in some experimental conditions manipulations may become blunter making the real source of fluency clearer, leading to discount effects. The other is that the factors we isolated may not have a clear effect on expectations. For instance by adding more levels of fluency we may increase

the needed variability of experiences to promote fluency effects, but we may also decrease the discrepancy between items because of an increase expectation of that discrepancy. And in some way levels of familiarity can be more prone to this reduction of discrepancy than levels of perceptual fluency. Alternatively, higher levels of familiarity may have lead participants to recognize previous presentation as a source of fluency and so to activate discounting effects (Oppenheimer, 2003, 2004; Schwarz & Clore, 2007; Whittlesea & Williams, 1998). The same discounting effect may have been promoted by increasing the proportion of familiar items. Familiarity may be a better cue to previous presentation activating discounting effects (but see below).

Nevertheless, taken together these data suggest that familiarity/fluency effects are associated with the pattern of data expected by the discrepancy hypothesis, but may be also turning evidence on a discounting effect.

Two specific moderators were isolated to directly test these discounting effects: type of judgment and duration range. We expected that if attention is called to the relevant source of the experienced fluency the effects were reduced. In line with this assumption the effects were stronger when only duration judgments are requested. But this is clearer only for perceptual fluency manipulations. No differences are found for conceptual fluency manipulations, neither for judgments that are relevant or irrelevant to the real source of the experienced fluency. The effect of the increase of duration range that was expected to promote discount effects was also only clearly detected in perceptual fluency manipulations studies. Thus in some way manipulations of conceptual fluency are less prone to discounting effects, which is contrary to what we stated above.

Implication for both theoretical approaches

The sets of hypothesis driven by each model have different support in this meta-analysis. Although there is no doubt that attentional mechanisms are associated with the familiarity/fluency duration effect (namely the process of sustained attention corroborated by slope effects), data seem to suggest that the effect is not dependent upon an assumption of an increased availability of resource to dedicate to time estimates (allocation attention). At least regarding the way attention was divided in this set of studies and with duration ranges we are focusing in this meta-analysis.

Thus the effect is more likely to occur because of the fluency experienced when processing the stimuli. Variables known to impact the magnitude of the experience of fluency (namely discrepancy) are also moderators of the fluency duration effect, making it likely that the level of discrepancy biases the experienced fluency. Additionally the impact of these processing feelings is more clear associated with ambiguity conditions, as has been demonstrated with the assumption that fluency serves as a heuristic for decision and judgment processes (Kahneman, 1973). But we should also expect that the (mis)attribution hypothesis should be counteracted if the awareness of the real source is available. Results suggest this occurs but only when manipulations are from perceptual fluency, making it more likely that these manipulations are prone to promote a misattribution than the manipulation of conceptual fluency.

The dissociation we frequently found between the moderations of conceptual and perceptual fluency effects, suggest that we should not take familiarity effects as totally explainable by the fluency account. Although perceptual and conceptual fluency are usually assumed to reflect a unitary construct (Alter & Oppenheimer, 2009) and result in the same general subjective experience of processing ease (e.g., Reber et al., 2004; Wurtz et al., 2008), this analysis suggests that that may not be the case (see also Silva, Garica-Marques & Mello, 2015). Perceptual fluency associated with a familiar stimulus is here shown to bias decisions and duration judgments, but familiarity doesn't promote itself a bias with the same characteristics. For instance, familiarity seems less prone to discounting effects than fluency. One hypothesis is that fluency is itself misattributed to familiarity (Garcia-Marques, Silva & Mello, 2016; Reber & Schwarz, 1999).

Also the fact that this meta-analysis shows the decision process associated with duration judgments to be highly relevant in results of different studies does not put aside the information processing model of time perception. Attention is needed to initialize the processing of the target stimulus and sustained attention mechanisms are shown to be highly relevant to monitor duration (as "*slope effects*" document) and support time estimation processes. But more relevant is that these models also assume a final decision phase following time estimates. Decision and judgments regarding duration may use such estimates or, as it has been repeatedly shown and documented in this paper, may simple rely on heuristics and feelings. In this phase the individual is expected to compare the actual experience of time with a memory standard in order to judge its duration as long vs. shorter or in a rating-scale continuum. The decisional bias that we are detecting in our analysis could represent that

process. Possible because time estimation is very short in the time range here addressed, the decision process become more relevant and better explains the effects found. But this is a question to be addressed in future studies.

Repetition

We added to the meta-analysis regarding familiarity duration effects an analysis of repetition effects. This occurs mainly because of the need to distinguish one effect from the other. But now we can specifically state that not only repetition within the temporal estimate task (estimation of duration of the same exemplar) as well repetition priming (estimates of an exemplar that is primed with itself) promotes effects that are opposite to the familiarity duration effect. The repetition priming manipulation is usually reported to be just one more manipulation of perceptual fluency (Jacoby, 1991; Jacoby & Witherspoon, 1982). However this manipulation clearly differs from other sets of fluency manipulations in their impact on duration estimates. The repetition-priming manipulation replicates the effects usually found with intra-trial repetition promoting an inverted effect.

These results pointing towards a third effect moderating time perception and duration judgments call for an extra theoretical root to explore the underlying mechanisms of non-temporal effects in time perception. Because a full model of perceived duration should account for these two effects (repetition and familiarity effects) future studies should address and contrast them. Those studies may find relevant the fact that repetition-priming effects are also explained with fluency and attentional accounts. Thus priming is thought to reflect facilitated perceptual processing of previously attended stimuli (Huber et al., 2008) and priming is thought to influence the way attention shifts, assuming that attention can easily be shifted to the repeated item (Sigurdardottir, Kristjánsson, & Driver, 2008; Becker (2008). Repetition priming is also not an homogeneous effect and it clearly separates previous familiarity from repetition. Repetition priming effects in lexical decision tasks were shown to be stronger for low-frequency words than for high-frequency words (e.g. Forster & Davis, 1984) and repetition priming was shown to attenuate response to the repetition of familiar faces and symbols, but exhibited an enhanced response to the repetition of unfamiliar stimuli (Henson, Shallice, & Dolan, 2000). Additionally, repetition priming seem to reflect activity modulations ranging from lower to higher perceptive levels, with this being highly depending on the stimulus, task, and context (Kristjánsson & Campana, (2010). Consequently, repetition priming, most often associated with neural attenuation for repeated presentation of

stimuli, was also shown in some studies to result in increases in neural responses. This increase occurrence is shown for instance when repeated stimuli lack perceptual fluency (Horner,& Henson, 2008) and when stimuli have no pre-existing associations or meaning (Henson, et al. 2000).

In addition repetition effects on oddball paradigms should be thought as a task that is overload in actively sustaining attention to targets serving to maintain bindings of repetition itself (Wheeler & Treisman, 2002; Xu & Chun, 2009) and that may have implication in monitoring stimuli duration. The oddball effect reflects attention switching from an attended to an unattended task-irrelevant event (usually more complex) which possible allows better detection of the initial presentation of the stimuli and favors sustained attention to its features. In addition oddball or unexpected stimuli being more salient are associated with an increase of arousal. Arousal is a factor known to be able to accelerate the pacemaker of a time processing model (Ulrich et. 2006).

A relevant feature to focus on is the time of the prime presentation. Negative repetition effects occur only within prime durations of 1000 ms, being inverted (and thus transformed in familiarity effects) when the prime is presented for 100ms (Huber et al. 2008). Evidence has suggested that oddball effects disappear when stimuli duration is too long - 300 ms (Seifried & Ulrich, 2010) and become positive when it is too short - 100 ms durations (Tse et al., 2004). Also when the interval between the repetitions is 2 s were found no repetition negative effects (Matthews, 2015, experiment 5).

Huber and O'Reilly (2003, see also Huber et al., 2008) propose this to be evidence that the repetition effect occurs because of an "activation-perceptive habituation" process to the prime, with habituation being braked if prime presentation is made shorter. Their model assumes that the experience of fluency is relative to previous activation of the stimuli the more the pre-activation the smaller the experience of fluency and thus time estimates. In this sense the model is at odds with the discrepancy hypothesis (Whittlesea & Leboe, 2003), suggesting that it only occurs when awareness of the prime or repetition influences their expectancy. But alternative hypothesis may be the awareness of the "repetition" itself allows a better identification of its source, which may prevent (mis)attributions to occur (e.g. Bornstein & D'Agostino, 1992, 1994).

Limitations

Although this meta-analysis has provided a useful summary of a wide range of data from a number of different studies it is important to note its limitations. First, the effect sizes associated with most of the reviewed studies that examined the relationship between familiarity and duration judgments were highly heterogeneous. Although this continues to suggest moderation effects, it also necessary to point out the effect as one that may not be reliable in different contexts. One of the reasons is likely to be the heterogeneity of this literature using many different experimental paradigms.

Second, the small number of studies that examined some of our moderators makes it difficult to conclude about the generality of the effects. This occurs for instance with regard to between participants repetition manipulations. There was also lack of reliability in the comparisons of conceptual or perceptual fluency analysis that is not balanced with regard some moderators. For instance regarding duration x fluency effects.

Third, in this meta-analysis we raise some hypothesis to "test" the information processing of time duration assumptions. However many other assumption underlie these models and were not able to be addressed in this meta-analysis. For instance we were not able to directly test the "*intercept effect*", showing the constant bias promoted by initial attention and the diagnostic value of fluency for time.

Future Orientations

Throughout this discussion we have call attention to issues that will need further empirical investigation. However many other features of the process of time perception need to be explored in order to fully understand the familiarity effect. We provide some examples in this section.

In order to better understand how familiarity interferes with the dynamic attentional process engaged in time perception, future research should directly focus on how familiarity impact on both initial and sustained attention mechanisms modulates time perception. For instance eye tracking fixations of familiar and unfamiliar stimuli (e.g., Althoff & Cohen, 1999; Hsiao & Cottrell, 2008) associated with time judgments or spatial cueing tasks should be shown to reduce familiarity duration effects. Studies also partially replicate Buhusi and Meck, (2006) interfering with sustained attention when processing time of familiar and unfamiliar stimuli. Future studies may use individual performance in divided and sustain

attention tests (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997) as moderators of their sensibility to familiarity duration effects.

In order to understand why the depletion of what may be resources needed to sustain selective attention to time, by allocating them to a secondary task, did not moderate the familiarity duration effect, future studies should manipulate this in the same experimental setting (given the meta-analytic comparison being performed between studies). For instance, we may follow the experimental paradigm used by Macar et al. (1994, 2004) manipulating familiarity. Such studies should also carefully attend to the range of duration provided and to the type of multiple tasks assume to interfere.

Throughout this paper we have been addressing familiarity duration effect as an overestimation effect. This "over" estimation is a "bias". But by assuming that familiarity allows more attention resources to be directed towards the stimuli, we should also expect familiarity to increase the sensitivity to real time, since attention was shown to impact this component (Brown, 2008. Grondin, 2010). No study until now has directly estimated both bias and sensitivity components of time judgments. In typical time discrimination task (bisection; Wearden, 1991) future studies should calculate the two components in order to better understand

Although the results of this meta-analysis suggest discounting effects occur (mainly with perceptual fluency manipulations) the effects were inferred by a between study comparison and coding some studies as more able to provide such discounting than others. Future studies should directly test within the same study, using for instance the experimental paradigm used by Bornstein and D'Agostino, (1994) or by Schwarz, (1998, Schwarz et al. 1998). That makes the source of the fluency highly explicit to participants.

In order to better understand the real diagnostic value of familiarity regarding time judgments, future studies could address the bidirectionality of the familiarity-duration link (Garcia-Marques, Mackie, Claypool, & Garcia- Marques, 2004; Converse, Sackett, Meyvis, Nelson, & Sackett, 2010) and assess the relationship between measures of perceived time perception and measures of fluency across different levels of duration (Reber et al., 1998; Forster et al, 2015). One way of assessing this relation between time and experience of fluency is by attending to the nature of fluency as a feeling. Fluency as a feeling is a hedonic marker (Winkielman ,Schwarz , Fazendeiro & Reber, 2003) being experienced as a positive feeling (Garcia-Marques & Mackie, 2000) with physiological correlates (Harmon-Jones & Allen, 2001; Winkielman & Cacioppo, 2001). This suggests that time may be in some way

related with the physiological activation promoted by the fluency with which a familiar stimuli is processed.

Conclusion

We embarked on this systematic review of the familiarity effect with the hope of clarifying different components of the effect that are usually disregarded by different approaches to time duration estimates/judgments. The phenomenon is an important psychological phenomenon that lies at the seam of cognitive perception models and social cognition judgments and decision psychology. Although different readers may focus more of their attention on particular aspects of this review and less on others, our intention has been to provide both a systematic review and a theoretical synthesis of the two approaches.

This meta-analysis is clear in clarifying how familiarity duration effect is related to attentional and fluency attributional processes.

An important aspect is of this analysis is that it suggests that it may be worthwhile to better separate the component of time representation from the judgment of time/duration. Bias in attention process may be more relevant to the process of representing time than judgment itself, whereas a set of other biases may be influencing our judgments (Cai & Wang, 2014; Rammsayer & Verner, 2015).

Besides this there is also another relevant issue taken from this analysis that is the challenge that this analysis makes of the unitary view of fluency construct (conceptual and perceptual fluency; see Alter & Oppenheimer, 2009). Our analysis suggests that this may not be the case (see also Silva, Garcia-Marques & Mello, 2015).

Appendix. Overview of the Meta-Analysis Database: Moderator Variables by Study

	Moderator												
Study	N	Treat	Levels	Dual	Stim	Trials	Temp	Range	Diff	Flu	FluT	Rep	g
Warm, Greenberg, & Dube (1964) - 1	45	W	L0	T1	VS	N0	E	G1	M0	F1	C	R0	
Warm & McCray (1969) - 1	48	W	L0	T1	VS	N0	E	G1	M0	F1	C	R0	
Warm & McCray (1969) - 1*	48	W	L0	T1	VS	N0	E	G1	M0	F11	F		
Mo & Michalski (1972) - 1	60	W	L1	T0	VI	N0	D	G1	M1	F9	F		
Mo & Michalski (1972) - 2	60	W	L1	T0	VI	N0	D	G1	M1	F9	F		
Devane (1974) - 1	48	W	L0	T1	VS	N0	E	G1	M0	F1	C	R0	
Devane (1974) - 1*	48	W	L0	T1	VS	N0	E	G1	M0	F11	F		
Schiffman & Bobko (1974) - 1	42	B	L1	T0	VI	N0	R	G2	M2	F7	F		
Avant & Lyman (1975) - 1	20	W	L1	T0	VS	N0	D	G0	M0	F8	F		
Avant & Lyman (1975) - 2a	20	W	L1	T0	VS	N0	D	G0	M0	F8	F		
Avant & Lyman (1975) - 2b	20	W	L1	T0	VS	N0	D	G0	M0	F8	F		
Avant & Lyman (1975) - 3	10	W	L0	T0	VS	N0	D	G0	M1	F7	F	R0	
Avant, Lyman & Antes (1975) - 1	25	W	L1	T0	VS	N0	D	G0	M0	F8	F		
Avant, Lyman & Antes (1975) - 2	23	W	L1	T0	VS	N0	D	G0	M0	F8	F		
Avant, Lyman & Antes (1975) - 4	20	W	L1	T0	VS	N0	D	G0	M0	F8	F		
Avant, Lyman & Antes (1975) - 5	10	W	L1	T0	VS	N0	D	G0	M0	F8	F		
Thomas & Cantor (1975) - 1	24	W	L0	T2	VI	N0	E	G0	M1	F9	F		
Thomas & Weaver (1975) - 1	20	W	L1	T1	VS	N1	E	G0	M1	F2	C	R0	
Cantor & Thomas (1976) - 1	10	W	L1	T0	VI	N1	D	G0	M1	F8	F		
Cantor & Thomas (1976) - 1*	10	W	L1	T0	VI	N1	D	G0	M1	F9	F		
Kowal (1976) - 1	24	W	L1	T2	AS	N0	E	G2	M2	F3	C	R0	
Thomas & Cantor (1976) - 1a	21	W	L0	T0	VI	N0	E	G0	M1	F9	F		
Thomas & Cantor (1976) - 1b	21	W	L0	T0	VI	N0	E	G0	M1	F9	F		
Avant et al (1977) - 2a	20	W	L0	T0	VI	N0	D	G0	M0	F7	F		
Cantor & Thomas (1977) - 1a	36	W	L1	T1	VI	N1	E	G0	M1	F7	F		
Cantor & Thomas (1977) - 1a*	36	W	L1	T2	VI	N1	E	G0	M1	F9	F		
Cantor & Thomas (1977) - 1b	15	W	L1	T1	VI	N1	E	G1	M1	F7	F		
Cantor & Thomas (1977) - 1b*	15	W	L1	T2	VI	N1	E	G1	M1	F9	F		
Schiffman & Bobko (1977) - 1	69	B	L1	T0	VI	N0	R	G2	M2	F1	C	R0	
Gomez & Robertson (1979) - 1a	16	B	L0	T0	VI	N0	E	G0	M1	F9	F		
Gomez & Robertson (1979) - 1b	16	W	L0	T0	VI	N0	E	G0	M1	F9	F		

Gomez & Robertson (1979) - 2	16	W	L0	T0	VI	N0	E	G1	M1	F9	F	
Long & Beaton (1980a) - 1	5	W	L1	T0	VI	N1	E	G0	M1	F9	F	
Long & Beaton (1980a) - 2	5	W	L1	T0	VI	N1	E	G0	M1	F8	F	
Long & Beaton (1980b) - 2	10	W	L1	T0	VI	N1	E	G0	M1	F8	F	
Robertson & Gomez (1980) - 1a	8	W	L0	T0	VI	N0	E	G0	M1	F7	F	
Robertson & Gomez (1980) - 1a*	8	B	L0	T0	VI	N0	E	G0	M1	F9	F	
Robertson & Gomez (1980) - 1b	8	B	L0	T0	VI	N0	E	G0	M1	F7	F	
Robertson & Gomez (1980) - 1b*	8	W	L0	T0	VI	N0	E	G0	M1	F9	F	
Robertson & Gomez (1980) - 1c	8	W	L0	T0	VI	N0	E	G0	M1	F7	F	
Robertson & Gomez (1980) - 1c*	8	W	L0	T0	VI	N0	E	G0	M1	F9	F	
Kowal (1981) - 1	30	W	L1	T1	AI	N0	E	G2	M2	F10	F	
Long & Beaton (1981) - 3a	6	W	L1	T0	VI	N1	E	G0	M1	F8	F	
Long & Beaton (1981) - 3b	6	W	L1	T0	VI	N1	E	G0	M1	F8	F	
Poynter & Homa (1983) - 1	17	W	L1	T1	VI	N0	R	G2	M2	F10	F	
Poynter & Homa (1983) - 3	16	W	L1	T0	VI	N0	D	G2	M0	F7	F	
Witherspoon & Allan (1985) - 1	21	W	L0	T1	VS	N0	E	G0	M1	F4	C	R0
Witherspoon & Allan (1985) - 2	21	W	L0	T0	VS	N0	E	G0	M1	F4	C	R0
Witherspoon & Allan (1985) - 3	24	W	L0	T1	VS	N0	E	G0	M1	F4	C	R0
Kowal (1987) - 1a	34	W	L0	T2	AI	N0	E	G2	M2	F3	C	R0
Kowal (1987) - 1b	24	W	L0	T2	AI	N0	E	G2	M2	F3	C	R0
Kowal (1987) - 2a	19	W	L0	T2	AI	N0	E	G2	M2	F3	C	R0
Kowal (1987) - 2b	56	W	L0	T2	AI	N0	E	G2	M2	F3	C	R0
Kowal (1987) - 3a	6	W	L0	T0	AI	N0	E	G2	M2	F3	C	R0
Kowal (1987) - 3b	8	W	L0	T0	AI	N0	E	G2	M2	F3	C	R0
Marohn & Hochhaus (1988) - 1	22	W	L1	T1	VS	N1	E	G0	M1	F5	C	R0
Marohn & Hochhaus (1988) - 1*	22	W	L1	T1	VS	N1	E	G0	M1	F6	F	R2
Marohn & Hochhaus (1988) - 2	12	W	L0	T1	VS	N0	E	G0	M1	F6	F	R2
Marohn & Hochhaus (1988) - 3	17	W	L0	T1	VS	N0	E	G0	M1	F5	C	R0
Reingold & Merikle (1988) - 1	20	W	L0	T0	VS	N1	D	G0	M0	F2	C	R0
Reingold & Merikle (1988) - 2	20	W	L0	T0	VS	N1	D	G0	M1	F2	C	R0
Reingold & Merikle (1988) - 3	40	W	L0	T0	VS	N1	D	G0	M0	F2	C	R0
Stoyanova & Bohdanecky (1988) - 1	6	W	L0	T1	VI	N1	E	G0	M1	F3	C	R0
Jones & Boltz (1989) - 1	16	W	L1	T0	AI	N1	D	G2	M0	F10	F	
Hochhaus, Swanson, & Carter (1991) - 1	16	W	L0	T0	VS	N1	E	G1	M1	F1	C	R0

Hochhaus, Swanson, & Carter (1991) - 2	16	W	L0	T0	VS	N1	E	G0	M1	F1	C	R0
Hochhaus, Swanson, & Carter (1991) - 3	26	W	L1	T0	VS	N1	E	G0	M1	F1	C	R0
Hochhaus, Swanson, & Carter (1991) - 3*	26	W	L1	T0	VS	N1	E	G0	M1	F2	C	R0
Hochhaus, Swanson, & Carter (1991) - 3**	26	W	L0	T0	VS	N1	E	G0	M1	F8	F	
Hochhaus, Swanson, & Carter (1991) - 4	16	W	L0	T0	VS	N0	D	G0	M0	F1	C	R0
Hochhaus, Swanson, & Carter (1991) - 4*	16	W	L0	T0	VS	N0	D	G0	M0	F2	C	R0
Paller et al. (1991) - 1	16	W	L0	T0	VS	N0	E	G1	M1	F4	C	R0
Paller et al. (1991) - 2	18	W	L0	T0	VS	N0	E	G1	M1	F4	C	R0
Whittlesea (1993) - 6	30	W	L0	T1	VS	N1	D	G0	M1	F8	F	
Whittlesea (1993) - 6*	30	W	L0	T1	VS	N1	D	G0	M1	F6	F	R2
Chastain & Ferraro (1997) - 1	10	W	L0	T0	VS	N1	E	G1	M1	F1	C	R0
Chastain & Ferraro (1997) - 1*	10	W	L0	T0	VS	N1	E	G1	M1	F11	F	
Chastain & Ferraro (1997) - 2	18	W	L0	T0	VS	N1	E	G1	M1	F7	F	
Chastain & Ferraro (1997) - 2*	18	W	L0	T0	VS	N1	E	G1	M1	F11	F	
Chastain & Ferraro (1997) - 4a	10	W	L1	T0	VS	N1	E	G1	M1	F9	F	
Chastain & Ferraro (1997) - 4b	12	W	L1	T0	VS	N1	E	G1	M1	F9	F	
Chastain & Ferraro (1997) - 5a	18	W	L0	T0	VS	N1	E	G0	M1	F1	C	R0
Chastain & Ferraro (1997) - 5a*	18	W	L0	T0	VS	N1	E	G0	M1	F11	F	
Chastain & Ferraro (1997) - 5b	18	W	L0	T0	VS	N1	E	G2	M2	F1	C	R0
Chastain & Ferraro (1997) - 5b*	18	W	L0	T0	VS	N1	E	G2	M2	F11	F	
Chastain & Ferraro (1997) - 6	18	W	L0	T1	VS	N1	E	G1	M1	F1	C	R0
Boltz et al (1998) - 2	32	W	L1	T2	AI	N0	E	G2	M2	F3	C	R0
Masson & Caldwell (1998) - 1	30	W	L1	T0	VS	N1	E	G0	M1	F4	C	R0
Masson & Caldwell (1998) - 2	30	W	L1	T0	VS	N1	E	G0	M1	F4	C	R0
Brown & Boltz (2002) - 1	36	W	L1	T1	AI	N0	R	G2	M2	F10	F	
Brown & Boltz (2002) - 1*	36	W	L1	T2	AI	N0	R	G2	M2	F10	F	
Brown & Boltz (2002) - 2	89	W	L1	T1	AS	N0	R	G2	M2	F10	F	
Brown & Boltz (2002) - 2*	89	W	L1	T2	AS	N0	R	G2	M2	F10	F	
Avni-Babad & Ritov (2003) - 3	39	B	L0	T1	VS	N0	E	G2	M0	F10	F	
Kleider & Goldinger (2004) - 7	57	W	L0	T2	VI	N0	E	G2	M2	F4	C	R0
Reber, Zimmermann & Wurtz (2004) - 1	16	W	L0	T0	VS	N1	E	G0	M1	F2	C	R0
Reber, Zimmermann & Wurtz (2004) - 2a	20	W	L0	T0	VS	N1	E	G0	M1	F2	C	R0
Reber, Zimmermann & Wurtz (2004) - 2b	20	W	L0	T0	VS	N1	E	G1	M1	F2	C	R0
Reber, Zimmermann & Wurtz (2004) - 5	49	W	L0	T0	VS	N1	E	G0	M1	F2	C	R0

Tse et al. (2004) - 7	19	W	L0	T0	VI	N1	D	G2	M2			R1
Ono & Kawahara (2005) - 1	16	W	L0	T0	VI	N0	P	G2	M0			R1
Ono & Kawahara (2005) - 2	12	W	L0	T0	VI	N1	P	G2	M0			R1
Noguchi et al (2006) - 1a	15	W	L0	T0	VI	N1	D	G1	M1			R2
Taylor & Lupker (2006) - 1	30	W	L1	T1	VS	N0	P	G1	M0	F1	C	R0
Taylor & Lupker (2006) - 1*	30	W	L1	T2	VS	N0	P	G1	M0	F2	C	R0
Taylor & Lupker (2006) - 2	40	W	L1	T1	VS	N0	P	G1	M0	F1	C	R0
Taylor & Lupker (2006) - 2*	40	W	L1	T2	VS	N0	P	G1	M0	F2	C	R0
Ulrich, Nitschke & Rammsayer (2006) - 1	24	W	L0	T0	VI	N1	D	G1	M2			R1
Ulrich, Nitschke & Rammsayer (2006) - 2	24	W	L0	T0	VI	N1	D	G1	M2			R1
Ulrich, Nitschke & Rammsayer (2006) - 3	40	W	L0	T0	VI	N1	D	G1	M2			R1
Mondillon et al (2007) - 1	47	W	L0	T0	VI	N1	D	G1	M2	F3	C	R0
Mondillon et al (2007) - 2	47	W	L0	T0	VI	N1	D	G1	M2	F3	C	R0
Ono & Kawahara (2007) - 1	20	W	L0	T2	VI	N1	E	G1	M1	F9	F	
Ono & Kawahara (2007) - 2	20	W	L0	T0	VI	N1	E	G1	M1	F9	F	
Ono et al. (2004) - 1	12	W	L1	T0	VS	N0	D	G1	M2	F4	C	R0
Ono et al. (2004) - 2	12	W	L1	T0	VS	N0	D	G1	M2	F4	C	R0
Ono et al. (2007) - 1*	14	W	L0	T1	VI	N1	P	G2	M0	F6	F	R2
Pariyadath & Eagleman (2007) - 4	8	W	L0	T0	VI	N1	D	G1	M0			R2
Pariyadath & Eagleman (2007) - 5	7	W	L0	T0	VI	N1	D	G1	M0			R2
Taylor & Lupker (2007) - 1	53	W	L0	T2	VS	N0	P	G1	M0	F2	C	R0
Xuan et al. 2007 - 1	24	W	L0	T0	VI	N1	D	G1	M2	F8	F	
Xuan et al. 2007 - 1*	24	W	L0	T0	VI	N1	D	G1	M2	F9	F	
Aubry et al. (2008) - 1a	36	W	L1	T0	VI	N1	D	G1	M2	F7	F	
Aubry et al. (2008) - 1b	36	W	L1	T0	VI	N1	D	G1	M2	F7	F	
Ono & Kawahara (2008) - 1	16	W	L0	T0	VS	N0	P	G2	M0	F4	C	R0
Ono & Kawahara (2008) - 1*	16	W	L0	T0	VS	N0	P	G2	M0	F5	C	R0
Cardaci et al (2009) - 1	65	W	L1	T0	VI	N0	E	G2	M0	F7	F	
Rhodes & McCabe (2009) - 1	117	B	L1	T0	VS	N0	E	G0	M1	F3	C	R0
Agrillo et al. (2010) - 1	16	W	L1	T0	AI	N0	R	G2	M2	F7	F	
Bruno et al. (2010) - 3	3	W	L0	T0	VI	N1	D	G1	M2	F8	F	
Zhou et al (2010) - 1	7	W	L0	T0	VI	N1	D	G1	M2	F6	F	R2
Mathews et al. (2011) - 1	14	W	L0	T0	VI	N1	D	G1	M1			R2
Mathews et al. (2011) - 1a	24	W	L0	T0	VI	N1	D	G1	M1	F8	F	

Mathews et al. (2011) - 1b	24	W	L0	T0	VI	N1	D	G1	M1	F8	F	
Mathews et al. (2011) - 1c	24	W	L0	T0	VI	N1	D	G1	M1	F8	F	
Mathews et al. (2011) - 1d	24	W	L0	T0	VI	N1	D	G1	M1	F8	F	
Mathews et al. (2011) - 2	20	W	L1	T0	VI	N1	D	G1	M1			R2
Mathews et al. (2011) - 2a	24	W	L0	T0	AI	N1	D	G1	M1	F8	F	
Mathews et al. (2011) - 2b	24	W	L0	T0	AI	N1	D	G1	M1	F8	F	
Mathews et al. (2011) - 3a	31	W	L0	T0	VI	N0	E	G1	M2	F8	F	
Mathews et al. (2011) - 3a	22	W	L0	T0	VI	N1	E	G1	M2			R2
Mathews et al. (2011) - 3b	31	W	L0	T0	VI	N0	E	G1	M2	F8	F	
Mathews et al. (2011) - 3b	20	W	L0	T0	VI	N1	P	G1	M0			R2
Mathews et al. (2011) - 4	27	W	L0	T0	VI	N1	P	G1	M2			R2
Schindel et al. (2011) - 2	12	W	L0	T0	VI	N1	D	G1	M2	F8	F	R2
Schindel et al. (2011) - 3	8	W	L1	T0	VI	N1	D	G1	M2			R2
Pariyadath & Eagleman (2012) - 1	11	W	L1	T0	VI	N1	D	G1	M1			R2
Pariyadath & Eagleman (2012) - 2a	9	W	L1	T0	VI	N1	D	G1	M1			R2
Pariyadath & Eagleman (2012) - 2b	16	W	L1	T0	VI	N1	D	G1	M1			R2
Verner & Rammsayer (2012) - 1	36	W	L0	T1	VI	N0	R	G1	M2	F9	F	
Yates (2012) - 1	16	W	L0	T0	VI	N1	D	G1	M2	F9	F	
Yates (2012) - 2	16	W	L0	T0	VI	N1	D	G1	M2	F9	F	
Kim & McAuley (2013) - 1	72	W	L0	T0	AI	N1	D	G1	M1			R2
Varakin (2013) - 1	17	W	L0	T0	VI	N1	D	G1	M2	F7	F	
Varakin (2013) - 2	26	W	L0	T0	VI	N1	D	G1	M2	F7	F	
Varakin (2013) - 3	16	W	L0	T1	VI	N1	D	G1	M2	F7	F	
Folta-Schoofs (2014) - 1	21	W	L1	T0	VI	N1	P	G2	M0	F7	F	
Palumbo et al (2014) - 1b	16	W	L1	T0	VI	N1	E	G1	M2	F7	F	
Palumbo et al (2014) - 2b	25	W	L1	T0	VI	N1	E	G1	M2	F7	F	
Rammsayer & Verner (2014b) - 1	40	W	L0	T0	VI	N0	R	G1	M2	F9	F	
Zhou et al (2014) - 1a	16	W	L0	T0	VI	N1	D	G1	M2			R2
Zhou et al (2014) - 1b	16	W	L1	T0	VI	N1	D	G1	M2			R2
Zhou et al (2014) - 3	16	W	L0	T0	VI	N1	D	G1	M2			R2
Birngruber (2015a) - 1	40	W	L0	T0	VI	N1	D	G1	M2			R2
Birngruber (2015a) - 2	40	W	L0	T0	VI	N1	D	G1	M2			R2
Birngruber (2015a) - 3	40	W	L0	T0	VI	N1	D	G1	M2			R2
Birngruber (2015b) - 1	32	W	L0	T0	VS	N1	D	G1	M1			R2

Birngruber (2015b) - 2	32	W	L0	T0	VS	N1	D	G1	M1			R2
Horr &Luca (2015) - 1	24	W	L0	T0	VI	N1	D	G1	M2	F10	F	
Horr &Luca (2015) - 2	24	W	L0	T0	VI	N1	D	G1	M2	F10	F	
Matthews (2015) - 1a	19	W	L0	T0	VI	N1	D	G1	M0			R2
Matthews (2015) - 1b	65	W	L0	T0	VI	N1	D	G1	M0			R2
Matthews (2015) - 2a1	18	W	L0	T0	VI	N1	E	G1	M0	F6	F	R2
Matthews (2015) - 2a2	38	W	L0	T0	VI	N1	E	G1	M0	F6	F	R2
Matthews (2015) - 2b	35	W	L0	T0	VI	N1	E	G1	M0	F6	F	R2
Matthews (2015) - 3	42	W	L0	T0	VI	N1	E	G1	M1	F6	F	R2
Matthews (2015) - 4a	44	W	L0	T0	VI	N1	D	G1	M0			R2
Matthews (2015) - 4b	34	W	L0	T0	VI	N1	R	G1	M0	F6	F	R2
Matthews (2015) - 5	31	W	L0	T0	VI	N1	D	G1	M0			R2
Matthews (2015) - 7	33	W	L0	T0	VI	N1	D	G1	M0			R2
Rammsayer & Verner (2015) - 1a	30	W	L0	T0	VI	N0	R	G1	M2	F9	F	
Fernandes & Garcia-Marques (2016a) - 1	100	W	L0	T0	VI	N0	D	G1	M2	F4	C	R0
Fernandes & Garcia-Marques (2016b) - 1	27	W	L0	T0	VI	N0	E	G1	M2	F4	C	R0

Note: The study coding is described in Table 1.

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Empirical Article 2

Familiarity effects in the bias and sensitivity components of duration discrimination

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Abstract

Previous studies have shown that the duration of more familiar stimuli is perceived to be longer than the duration of a less familiar stimulus. Although the effect has been associated with a bias in time estimation, no previous studies have compared the bias and sensitivity components of these judgments. In this paper, we used those components to separate the explanative power of the two most prominent explanations of the phenomena, the attentional interference hypothesis and the fluency-attribution hypothesis. The results suggest that familiarity impacts both components in two different directions, such that an increase in discriminability is associated with a decreased promotion of bias.

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Key words: Duration judgments; familiarity; sensibility; bias; attention

Familiarity effects in the bias and sensitivity components of duration discrimination

Introduction

Anecdotic descriptions suggest that when people have a face-to-face encounter with a familiar person in another country, the time of the encounter is extended. A similar effect has been reported when someone hears familiar words among unknown words spoken in a foreign language.

The duration lengthening exhibited in these anecdotic experiences has strong experimental support. Systematically, studies have shown that the duration of more familiar stimuli is perceived to be longer than the duration of a less familiar stimulus. This occurs either when familiarity is induced by experimentally pre-exposing individuals to those stimuli to different degrees (e.g., Kleider & Goldinger, 2004; Masson & Caldwell, 1998; Ono & Kawahara, 2008; Paller, Mayes, McDermott, Pickering, & Meudell, 1991; Witherspoon & Allan, 1985), or when the chosen stimuli already vary in familiarity to them (e.g., word used frequency in language, Chastain & Ferraro, 1997; Warm, Greenberg, & Dube, 1964; words versus non-words, Reber, Zimmermann, & Wurtz, 2004; Reingold & Merikle, 1988; subject expertise, Rhodes & McCabe, 2009).

The demonstrated familiar temporal overestimation in prospective timing judgments has been explained by some researchers (e.g., Chastain & Ferraro, 1997; Hochhaus, Swanson, & Carter, 1991; Warm & McCray, 1969) as promoted by attentional mechanisms (Brown, 2010; Thomas & Weaver, 1975; Zakay, & Block, 1996). The attentional interference hypothesis is framed within an internal-clock model, which suggests that attention plays a critical role in monitoring and detecting temporal information, normally hypothesized as pulses emitted by a pacemaker (e.g., Gibbon, Church, & Meck, 1984; Thomas & Weaver, 1975; Zakay & Block, 1996). The assumption is that attention controls a switch that allows the pulses to be counted (i.e., accumulated) until the end of the interval to be timed, representing its subjective duration. If attention is moved away from temporal features, as in the case of dual task conditions, or shared (by instruction) in specific amounts with non-temporal features, duration judgments typically become shorter (e.g., Brown, 1985; Brown & Merchant, 2007; Coull, Vidal, Nazarian, & Macar, 2004; Hicks, Miller, Gaes, & Bierman, 1977; Macar, Grondin, & Casini, 1994; Zakay, 1989; for a meta-analysis, see Block, Hancock, & Zakay, 2010). By diverting from temporal information, this information is lost –

pulses are not detected – and consequently, the shorter the time representation will be (e.g., Lejeune, 1998; Zakay & Block, 1996). Familiarity effects occur because familiar stimuli are represented in a more elaborate and detailed way in memory and can subsequently be processed more superficially, requiring less encoding effort than unfamiliar stimuli. This processing efficiency frees attention resources (Johnston, Hawley, Plewe, Elliot, & DeWitt, 1990; Parks & Hopfinger, 2008) from a limited capacity (see Kahneman, 1973) to attend temporal features of familiar stimuli, increasing temporal detection and, consequently, lengthening the duration judgment (Chastain & Ferraro, 1997; Hochhaus et al., 1991; Warm & McCray, 1969).

An alternative approach is one that argues that the familiarity overestimation of temporal features is supported by an inferential process (e.g., Kleider & Goldinger, 2004; Reber et al., 2004; Witherspoon & Allan, 1985) that attributed features of processing familiarity stimuli to time. The model assumes a shift in decision criterion of time judgments associated with familiar stimuli, which has also been assumed with regard to other types of judgments (e.g., Kahneman & Tversky, 1973; Schachter & Singer, 1962; Schwarz, 2004). Processing efficiency associated with familiarity has a subjective experience component – a feeling of ease or processing fluency – which is used as a metacognitive cue for judgments across a wide range of domains (for a review see Reber, Wurtz, & Zimmermann, 2004; Schwarz, 2004). By default, the fluency of processing is misattributed to the dimension being evaluated (i.e., fluency-attribution hypothesis, Jacoby & Dallas, 1981), even if it is not a direct result of a cognitive operation that objectively contributes to this judgment (see Oppenheimer, 2008). For example, individuals judge fluent stimuli (based on familiarity) to be more likable (Bornstein & D'Agostino, 1992; Zajonc, 1998), clearer (Jacoby, Allan, Collins, & Larwill, 1988; Whittlesea, Jacoby, & Girard, 1990), truer (Begg & Armour, 1991; Garcia-Marques, Silva, & Mello, 2016), and more understandable (Carroll & Masson, 1992) than less fluent stimuli. Thus, it is plausible that processing fluency impacts duration judgments in similar ways, as previously claimed by Jacoby and Dallas (1981). This relationship is not arbitrary. The individuals tend to attribute a familiarity-based fluency to an appropriate source as diagnostic information (Oppenheimer, 2008; Schwartz, 2004; Whittlesea & Williams, 2000).

According to Signal Detection Theory, detecting a stimulus as one with a long versus a short duration depends on two parameters: sensibility and bias (e.g., Green & Swets, 1966/1974; Macmillan & Creelman, 2005). Sensitivity refers to the ability to discriminate

(signal from noise) one duration from another (see Killeen, Fetterman, & Bizo, 1997), whereas the response bias refers to the criteria (or threshold based on signal strength) used for judging an interval as having a specific duration. A fluency-attribution model of familiarity time overestimation assumes it to be the results of a bias effect, one promoted by the fluency of processing that stimulus. Because the estimation is not based on objective temporal information, which only signals an overall tendency to respond “long (vs. short) duration” to familiar stimuli. This fluency-attribution model assumes that fluency (which is noise) is confounded by a signal (i.e., duration), and its strength is used as criteria to misjudge the actual duration. It is not expected that increasing stimulus fluency has any benefit in sensitivity because it does not have any objectively informative value for judgment. For example, more familiarity with statements whose truth is not known does not lead to a better discrimination between true and false statements (e.g., Silva, Garcia-Marques, & Mello, 2015; Masson, Carroll, & Micco, 1995).

On the other hand, internal-clock models predict that variations in attention will impact not only duration judgment bias but also duration sensibility (Brown, 2008; Creelman, 1962; Grondin, 2010; Thomas & Weaver, 1975). Bias and sensibility (and its functional relation) are incorporated in different models of time perception, indexed, respectively, by duration judgment and variability (e.g., Gibbon et al., 1984; Killeen, et al., 1997). It has been argued that the variable onset and offset latencies of the switch, which mark the interval to be judged, are the cause of variance in temporal perception. These marking errors caused by variations in attention monitoring explains effects in the interval temporal structure and consequent changes in sensitivity (see Grondin, 2010). Indeed, a decrease in temporal sensitivity in attentional overload conditions, such as those created by dual task manipulations, has been observed (e.g., Brown, 1997; Macar, et al., 1994). A meta-analysis (Block et al., 2010) (45 studies) suggests a significant drop in sensitivity induced by attentional load. These assumptions have also correlated the expectation that the impact of familiarity on both indexes will relate negatively. If the effect of familiarity on sensitivity is associated with an increase of attention to the temporal dimension of the stimulus itself, we should expect familiarity to be less prone to bias for those judgments as sensitivity increases.

Until now, most papers have disregarded the impact of familiarity on duration sensitivity isolated from bias estimates. The measurements reported in the literature are the means of duration judgments primarily accessed with verbal estimation (e.g., Devane, 1974;

Warm et al., 1964) and time scaling methods (e.g., Chastain & Ferraro, 1997; Witherspoon & Allan, 1985), which index familiarity temporal effects in general.

In the present article, we expand the existing knowledge by testing the effect of familiarity on bias and sensitivity and its functional relationships, as they are informative of the explanatory mechanisms underlying familiarity effects over time perception. We followed the Kleider and Goldinger (2004) familiarity manipulation, pre-exposing emotionally neutral faces with different familiarity levels, and used a temporal discrimination task (i.e., bisection task) to calculate independent bias and sensitivity indexes (Macmillan 2002; Macmillan & Creelman 2005; Killeen et al., 1997). We expect that a sensitivity effect and its negative correlation with the bias effect will support the attentional interference hypothesis to the detriment of the fluency-attribution hypothesis as a plausible explanatory mechanism of familiarity effects in time estimation.

Method

Subjects and design

One-hundred (79 females) first- and second-year psychology students (ISPA, Portugal) with a mean (SD) age of 21.4 (8.5) years participated in this experiment for partial course credit. All reported normal or corrected-to-normal vision and were blinded to the task and the purpose of the experiment. A within-subjects factorial design 2 (familiarity: no prior exposure vs. prior exposure) x 7 (duration: 400 to 1.600 ms) defined the testing procedure. Subjects were tested in eleven group sessions. The sample size allowed a power >.90 to estimate a moderate effect size (with $\alpha = .05$) with a correlation between repeated measures = .20 (Faul, Erdfelder, Lang, & Buchner, 2007).

Apparatus

The experiments were programmed with E-Prime 1.1 (Schneider, Eschman, & Zuccolotto, 2002a, b) and run individually on Hewlett-Packard computers with 19-inch monitors running at 100 Hz.

Stimuli. One hundred and forty seven non-emotional/neutral faces were selected from the MacBrain Face Stimulus Set (Tottenham et al., 2009) and the Lifespan Database of Adult Facial Stimuli (Minear & Park, 2004). The stimuli from both databases were re-sampled to be

12 x 16 cm in size, grey-scaled (16-bit), matched to luminance and contrast, and presented on a white background. The appearance age of the chosen faces was set to vary between 18 and 35 years old.

Experimental task

Prior exposure. Subjects were asked to complete a "familiarization" task that served to manipulate prior exposure to the target. They were told to pay attention to each of the target faces (98, half-females), presented for 1000 ms each, intermixed with a blank white screen (500 ms).

Temporal task. Subjects performed a two-forced choice categorization of time intervals (bisection task) that consisted of a training phase and a test phase. First, subjects were trained to press the "S" key on the keyboard after the presentation of a short standard stimulus duration (400 ms) or to press the "L" key after the presentation of a long standard stimulus duration (1.600 ms), both represented by a neutral stimulus (i.e., black square). The two standard durations (long/short ratio of 4:1) were presented five times each in alternation and then five times each randomly presented (50% probability of appearance). Categorization correctness feedback was provided on the screen ("correct" or "incorrect") after each training trial. In the test phase, subjects were required to categorize each of the seven stimulus durations (i.e., 400, 600, 800, 1000, 1200, 1400, and 1600 ms) using the learned category boundaries (short and long) and an implicit standard duration (ISD, middle duration: 1000 ms). Only half of the "old" faces were presented randomly among 49 "new" faces (7 durations x 7 replicas) in a total of 98 trials. The inter-trial interval varied randomly between 1000 and 2000 ms.

Dependent Measures

Response proportions. Individual psychophysical functions for each participant and condition were plotted, relating the proportion of "long" responses [P(R_L)] to each actual duration.

PSE and SD. The value of t (estimated duration) at which the proportion of "long" and "short" responses occur with the same probability, P(R_L)=.5, for the perceiver is often referred as point of subjective equality (PSE) and interpreted as the duration subjectively

equidistant from anchor duration values (in this case, 400 and 1.600 ms). PSE (μ) is the mean of the criterion dispersion and the standard deviation (SD) of its fluctuation (across the duration range) offers an index of temporal sensitivity/discrimination (see Macmillan & Creelman, 2005). SD (σ) is also proportional to the slope of the psychophysical function in the vicinity of the PSE, defined as the minimal interval necessary to distinguish between anchor durations. PSE (μ) and SD (σ) were estimated using a Pseudo-Logistic Model (PLM; Killeen, et al., 1997) fit for each individual psychophysical function. GraphPad Prism software (La Jolla, CA) was used to implement and run the non-linear least-square regression algorithm with the following equation (Killeen et al, 1997, Eq. 2):

$$P(R_L) = \left[1 + exp\left(\frac{\mu - t}{\frac{\sqrt{3}}{\pi}\sigma}\right)\right]^{-1}$$

Following the assumption of dominant scalar variance in perceived time (Allan, 2002; Killeen et al., 1997), the corresponding fits were good, with a mean proportion of variance of .95.

Results

To contrast the attentional interference hypothesis and the fluency-attribution hypothesis as a plausible explanatory mechanism of familiarity effects over time, we analyzed the effects of familiarity on the proportion of "long" responses and on the bias and sensitivity components, testing their relationship by regressing one over the other.

Familiarity effects. Familiarity impacted the proportion of "*long*" responses provided by perceivers for the given actual durations. Results from a 2 (familiarity: no prior exposure vs. prior exposure) x 7 (duration: 400 to 1.600 ms) repeated measures ANOVA showed the expected main effect of duration, $F(6, 594) = 1163.33$, $p < .001$; $\eta_p^2 = .92$, $MSE = .029$, and the expected main effect of prior exposure, $F(1, 99) = 8.30$, $p < .006$; $\eta_p^2 = .08$, $MSE = .013$. Following the literature, the duration of familiar faces (M=.534) was overestimated in relation to novel ones (M=.516). Moreover, this familiarity effect was not qualified by the actual duration of the stimulus, $F(6, 594) = 1.92$, $p = .075$; $\eta_p^2 = .02$, $MSE = 0.014$.

Bias and sensitivity effects. As shown in *Figure 1A*, familiarity effects were associated with differently skewed psychophysical functions. Compared to two levels of familiarity with regard to sensitivity (standard deviation means), we found a significant effect, $t(99) = 2.36$, p

= .020, d = .24, showing that familiarity had a positive impact on temporal discriminability. We also contrasted the two familiarity conditions with regard to bias estimates, PSE, and results suggest that bias was higher for new faces than for familiar faces, $t(99) = 2.65$, $p < .01$, $d = .27$.

Regression analysis. To test the relationship between the impact of familiarity over both components for each participant, we calculated the size of the effect of familiarity for PSE and for SD by subtracting the PSE for previously processed faces from the PSE for novel faces and the SD values from the familiar condition from that of the novel condition. The plotted positive correlation shown in *Figure 1B* was significant, $r = .46$, $t(99) = 5.08$, $p < .001$.

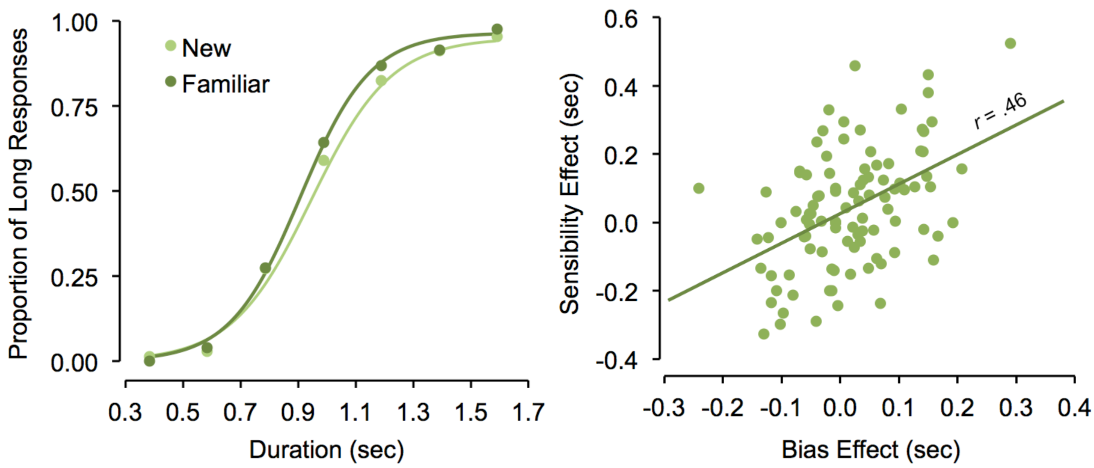

Figure 1. In the left panel (*A*), the psychometric curves for the familiar and unfamiliar conditions are represented by the plot of the means of the proportion of "long" responses against each of the seven actual durations, and the right panel (*B*) shows the scattered plot between individual sensibility (i.e., $SD_{new} - SD_{familiar}$) and bias effects (i.e., $PSE_{new} - PSE_{familiar}$) derived from individual psychometric curves.

SD and PSE were also positively correlated in both conditions (*familiar*, $r = .43$, $p < .001$, and *novel*, $r = .36$, $p < .001$); therefore, the correlation between the SD and PSE familiarity effects also implies a mediation process in a within-subjects treatment (see Judd, Kenny and McClelland, 2001). Judd et al. (2001) showed that the only relationship between PSE and SD (full model is, $F(2,97) = 12.77$, $p < .001$, $r^2 = .21$) is the mediational relationship ($\beta = .456$, $p < .001$ with moderation effect been inexistent, $\beta = .001$, $p = .99$).

Discussion

The results of signal detection analysis over performance in a bisection task executed over a duration range (0.4-1.6 s) suggests that familiarity effects occur over both bias and sensitivity components and that these two effects are negatively correlated. This pattern of results was what we would expect if familiarity effects on time overestimation were dependent upon *attentional mechanisms.*

In addition to the corroboration of one explanation over the other, these data also suggest that a bias effect is more prone to occur when the discrimination effect is low. This is not the moderation of the overall sensitivity over bias effects induced by non-temporal manipulations, as has been suggested by the attributional approaches (Brown, 1998; Matthews, 2011), which suggests that participants that have greater difficulty in discriminating stimulus durations are those that anchored their judgments in non-temporal information. We found no evidence of this type of moderation. Our study suggests that familiarity biases duration judgments only when it does not favor a good discrimination. This feature of processing suggests that the two explanations can offer complementary clarity to the phenomena. When the familiarity level is not able to maintain an accurate time discrimination, it will start to influence participants by biasing their estimations. It is thus possible that the processing fluency detects an additional and independent process through which familiarity impacts time estimation. Nevertheless, this is not the entire story.

To our knowledge, only Witherspoon and Allan (1985, exp.1) explored the sensibility effects of familiarity by asking participants to simultaneously make an identification and a duration judgment of briefly presented target familiar and non-familiar words (i.e., 30 to 50 ms). Familiarity promoted a general bias for the time effect (c parameter). However, only when words were not identified did familiarity positively impact time sensitivity. Together with the use of very short durations, the non-temporal concurrent task likely consumed the attentional resources needed for discrimination (see Kleider & Goldinger, 2004). Future studies have explored the negative relationship between the impacts that familiarity exert over sensitivity and over bias should explore how these types of attentional constraints differently impact each component and their relationship.

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Empirical Article 3

Dynamics of facial electromyography predicts duration estimation

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Abstract

The hypothesis that subjective duration estimates are based on the dynamic accumulation of physiological changes and its concomitant feelings is addressed in this study, showing how dynamic facial electromyography (EMG) predicts duration judgments. Previous studies have shown that perceptual timing involves a dynamic representation of time in core regions of the neural motor system. Additionally, sustained attention mechanisms, which are critical to time perception, have been shown to be associated with an increase of muscle activity over the course of time (EMG gradients), so we hypothesized that facial muscle activity may index the subjective representation of time. To test this hypothesis, we asked participants to judge stimuli durations while we monitored the time course of the activity of the zygomaticus major and corrugator supercilii muscles, which we contrasted with the slow physiological responses of heart rate. In addition, we also address subjective duration bias effects of familiarity in both muscles, expecting them to also predict this biased subjective experience of time. The data support the view that facial EMG activity of the corrugator reflects objective time and that this relationship mediates subjective judgments of duration. In addition, our data show that the relevance of the EMG activity for time judgments is extended to zygomaticus major activity only because this muscle signals the bias that familiarity promotes in duration estimates.

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Keywords: duration judgments; facial muscle activation; corrugator supercilli; zygomaticus major; familiarity

Dynamics of facial electromyography predicts duration judgments

Our ability to perceive time is very accurate, which is fundamental for many aspects of cognition that unfold in time, and for virtually all behaviors, from performing simple to complex actions, such as crossing a busy street or coordinating social interactions (Buhusi and Meck, 2005; Gibbon, Malapani, Dale, & Gallistel, 1997). However, contrasting with other basic physical dimensions (such as vision and sound), the brain lacks a dedicated sensory system for processing time (Ivry and Schlerf, 2008; Coull, Cheng, & Meck, 2011).

Prospective time perception theories have been focusing on the integrated processes that enable a subjective representation of duration. One old proposal was that duration estimates would be based on the somatic components of feelings of effort related to the sustained attention experienced in that interval of time (Mach, 1890/1897; Guyau, 1890; Münsterberg, 1889; Marchetti, 2009). This proposal is based on somatic feelings and has been recently gathering support regarding the involvement of neural structures, such as the insular cortex (Craig, 2015, 2009a; Wittmann, 2013, 2009), both in mapping interoceptive states and in the representation of time. This brain region is likely to be the primary receptive brain area that integrates information about the somatic states of the body with emotional and cognitive experiences (Craig, 2009b, 2002). Its role in the experience of judgment has been shown by fMRI studies that have documented neural activation correlating with stimulus duration (Wittmann, et al., 2011; Wittmann, Simmons, Aron, and Paulus, 2010). This suggests that the integration of somatic, emotional and attentional states can offer the interoceptive awareness that supports our perception of time intervals (Meissner & Wittmann, 2011).

In this paper, we follow and extend this proposal by showing for the first time the engagement of two facial muscles known to integrate affective and attentional information (zygomaticus major and corrugator supercilii) in the subjective representation of time. The idea that these two muscles may be differently associated with temporal experiences stems from the following observations.

First, neurobiological research suggests that interval timing and time representation involve the motor system (Coull, et al., 2011; Schwartze, Rothermich, & Kotz, 2012; Wiener, Turkeltaub, Coslett, 2010). Although a distributed neural network has been identified in general time processing (e.g., Buhusi &Meck, 2005; Merchant, Harrington, & Meck, 2013),

only regions that are strongly implied in motor functions are consistently activated across fMRI studies and timing task conditions (see Wiener, et al., 2010 meta-analysis). These areas are the Supplementary Motor Area (SMA), the Inferior Frontal Gyrus (IFG) and some clusters of Basal Ganglia (BG). Remarkably, these regions are engaged even in explicit timing tasks that do not involve the planning or the execution of an actual motor response (e.g., discriminating the duration of one stimulus from that of another).

The neural brain activity in SMA has been shown to build up as a function of objective stimulus duration during the sustained process of timing (Coull, Charras, Donadieu, Droit-Volet, & Vidal, 2015; Wencil et al., 2010; see also Macar, Vidal, & Casini, 1999; Pfeuty, Ragot, & Pouthas, 2005 for electrophysiological evidence). This makes it likely that the SMA represents the core timing mechanism since it is able to represent the sequential cumulative processes that determine a magnitude representation for duration. This "climbing neural activity is isomorphic to the features attributed to an internal-clock phase in information-processing (IP) time perception models This clock phase is defined by a pacemaker emitting pulses (or time units) that flow to an accumulator (Gibbon, Church, & Meck, 1984; Treisman, Faulkner, Naish, & Brogan, 1990; Zakay & Block, 1997). In some variants of the IP model, selective attention regulates a switch or a gate (e.g., Buhusi & Meck, 2009; Zakay & Block, 1997) allowing the accumulation of time units during a given interval, which resembles the SMA neural climbing pattern and its involvement in selective attention to temporal information (Coull, Vidal, Nazarian, & Marcar, 2004; Henry et al., 2015; Morillon, Kell, & Giraud, 2009).

A relevant feature of SMA activity is that it is also related to sustained mental effort in interval timing (Livesey, Wall, & Smith, 2007; Pouthas et al., 2005; Tregellas, Davalos, & Rojas, 2006). Estimating duration involves both dynamic cognitive processes such as sustained attention (to continuously track temporal information) and working memory processes (to continuously integrate and maintain a cumulative representation of duration over time), which both require cognitive effort (Brown, 2008; Brown, Collier, & Night, 2013; Fortin & Schweickert, 2016; Lustig, Matell, & Meck, 2005; Ogden, Wearden, & Montgomery, 2014; Zélanti & Droit-Volet, 2011).

Sustained attention and effort were shown to be associated with an electromyographic (EMG) gradient (Malmo, 1965) during motor performance (e.g., Cacioppo & Dorfman, 1987; Svebak, et al., 1993) and mental effort (without motor output) (e.g., Cohen, Davidson, Senullis, Saron, & Weisman, 1992; Van Boxtel & Jessurun, 1993). It shows a continuously

steady rise of EMG activity that precipitates abruptly at the end of a task (for a review see Malmo & Malmo, 2000). This spontaneous EMG activity that is only built up in tasks requiring sustained attention could last from seconds to dozens of minutes and typically reflects only a muscle tension (or a covert action) (see Malmo & Malmo, 2000). These characteristics suggest a co-variation with physical (i.e., objective) time in a similar way to the climbing neural activity in SMA and theoretically underlie the possibility of an effective motor component in "pure" perceptual timing.

Second, time perception EMG gradients are only found in muscles with high percentages of Type I slow-twitch extrafusal fibers, which are extremely slow-adapting (Cohen et al., 1992; Goodmurphy & Ovalle, 1999; Malmo & Malmo, 2000). These are features only present in a sub-group of facial muscles that convey affective expressions (e.g., Cohen et al., 1992; Waterink & Van Boxtel, 1994; Van Boxtel & Jessurun, 1993; Van Boxtel & Van der Ven, 1978; Vaughn & McDaniel, 1969; Veldhuizen, Gaillard, & de Vries, 2003; Veldhuizen, Van Boxtel, & Waterink, 1998). Specifically, the frontalis and corrugator-supercilii muscles (with a high percentage of Type I fibers) show uninterrupted EMG gradients, whereas the orbicularis oculi and zygomatic-major muscles (with a much lower percent of Type I fibers) have failed to show EMG gradients in tasks requiring sustained attention and mental effort (e.g., Cohen et al., 1992; Waterink & Van Boxtel, 1994; Van Boxtel & Jessurun, 1993). This is not a surprise since the corrugator supercilii (CS), a muscle responsible for frowning (Cacioppo et al., 1986), has also been associated with the expression of focused attention (Cohen et al., 1999; 1992), the expression of mental effort (Van Boxtel & Jessurun, 1993; Veldhuizen et al., 2003) and the perception and feelings of effort (de Morree & Marcoa, 2012, 2010; Smith, 1989).

Third, the available proposals regarding duration estimates being based on the somatic components of feelings of effort related to the experience of sustained attention refer to brain regions that are directly or indirectly related to motor systems and interoceptive functions, integrating somatic feelings. Recent fMRI studies have shown a climbing neural activation in the insular cortex correlated with stimulus duration (Wittmann, et al., 2011, 2010; but see Kosillo, & Smith, 2010). This region, in tandem with motor regions, is the only additional brain region most consistently activated in perceptual timing, as shown in Wiener and collaborators' meta-analysis. This is consistent with the idea that subjective duration is based on the dynamic accumulation of physiological changes and its concomitant feelings (Wittmann, 2013).

In the present study, we explore for the first time the dynamic relation between EMG gradients in the corrugator supercilii and the zygomatic major with objective durations. We further explore their predictive value with regard to subjective duration. The heart rate slow physiological response will be continuously monitored during the task, assuming that this autonomic activity indexes both attention (e.g., Barry, 1984a, b; De Pascalis, Barry, & Sparita, 1995; Jennings, 1992, 1986) and timing (see Meissner & Wittmann, 2011; Otten et al., 2015).

To strengthen our test, we also address subjective duration bias effects by presenting participants stimuli that are made to vary in their degree of familiarity. Stimuli familiarity is a factor known to positively bias the perceived duration of a stimulus (e.g., Chastain & Ferraro, 1997; Kleider & Goldinger, 2004; Masson & Caldwell, 1998; Paller, Mayes, McDermott, Pickering, & Meudell, 1991; Reber, Zimmermann, & Wurtz, 2004; Witherspoon & Allan, 1985) and to promote a subjective experience of ease (vs. difficulty) that is compatible with the notion of a sense of reduced (vs. increased) mental effort (Alter & Oppenheimer, 2009; Reber, et al., 2004; Schwarz, 2004). Processing of an unfamiliar stimulus (a feeling of disfluency) is likely associated with an experience of more difficulty in information processing, being indexed by the activity of the corrugator (Cacioppo , Petty, & Morris, 1985; Larsen et al., 1992). An impact of processing fluency over the zygomaticus major would not be related to mental effort but instead to the hedonic positivity of familiar stimuli (e.g. Harmon-Jones & Allen, 2001; Winkielman & Cacioppo, 2001) since that muscle is the one responsible for smiling and positive affect (Cacioppo, Petty, Losch, & Kim, 1986; Dimberg, Thunberg, & Elmehed, 2000).

Participants' task will be to evaluate the duration of stimuli, which they were either previously made familiar to or not. We expect stimulus familiarity to bias duration judgments and that this effect over time will also be indexed by muscle activity.

Method

Participants. Twenty-seven Native Portuguese-speaking students (21 females) were recruited from different universities of Lisbon and were paid for their participation. Participants were right-handed, with no history of attention disorder and with normal/corrected-to-normal vision.

Design, Materials and Apparatus. The experiment was supported by a 2 x 2 x 5 repeated measure design with familiarity (prior exposure vs. new faces), block (first vs. second block) and stimuli duration (0.4, 0.7, 1.0, 1.3 and 1.6 s) as within-subject factors. The experimental tasks were programmed in E-Prime 2.0 software (Schneider, Eschman, & Zuccolotto, 2002), and the stimuli were presented on a 19-inch monitor (100 Hz) with a resolution of 800 x 600, against a white background at a distance of 60 cm from the participant. Responses were entered via a keyboard. We used 80 neutral faces (all females) from the Lifespan Database of Adult Facial Stimuli (Minear & Park, 2004). The apparent age of the chosen faces was set to vary between 18 and 35 years old. Additionally, 20 images of objects controlled for levels of familiarity and valence (both neutral) selected from Ficheiro de Imagens Multicategoriais (Prada & Garcia-Marques, 2006) were also used in the training phase. The stimuli from both databases were re-sampled to have a visual angle of approximately 10°, gray-scaled (16-bit), matched for luminance and contrast, and presented on a white background.

Facial EMG and ECG Recording. Electrocardiography (ECG) and electromyographic (EMG) signals were collected using a Biopac MP100 system equipped with ECG100C and EMG100C amplifiers (Biopac Systems Inc., Goleta, CA). Both measures were amplified by a factor of 5,000 and sampled at 1,000 Hz frequency. Bipolar facial EMG (fEMG) signals were continuously recorded on the left Zygomaticus Major and Corrugator Supercilii muscles following electrode placements recommended by Fridlund and Cacioppo (1986). Two 4-mm Ag/AgCl electrodes (Biopac EL254S) were placed along the muscle fibers over each site with 1.5 cm between electrode centers. The skin surface at the mentioned sites was cleansed (70% isopropyl alcohol) and gently abraded (ElPrep gel, Biopac) before placing the electrodes filled with suitable conductive gel (i.e., Gel100, Biopac). fEMG signals were recorded with an online 10-Hz low cutoff filter, and a 500 Hz high cutoff filter. At recording, the ECG signal was bandpass filtered (0.5 and 35 Hz) and accessed using a standard 3 leads montage (Einthoven lead 2 configuration) in which the electrodes (Biopac EL503) were placed on the right collarbone and the lower left and right ribcage. Other physiological measures were collected (i.e., skin conductance) to be reported elsewhere. The ground electrode for fEMG measures was in the left-hand (i.e., skin conductance electrodes, accordingly with the guidelines of Biopac).

Procedure. All procedures were approved by the ISPA – Instituto Universitário Ethics Review Board, and participants provided written consent prior to the study. Participants arrived at the lab alone, and after signing the informed consent were asked to sit in front of a computer screen on an individual boot. The experimenter then took time to place the electrodes and explain to the participants that he would leave the room, returning by the time the experiment finished, and that all instructions would be presented on the computer screen. The experimenter then went to an adjacent room where he could control and monitor the physiological measurement. All instructions were provided on the computer screen in the beginning of the experiment that consisted in a familiarization task and a temporal task. The whole experimental session took approximately 50 min.

Familiarization task. Subjects were first asked to complete a "familiarization" task that served to manipulate prior exposure to the target faces. Subjects were told that they had to be extremely attentive to each of the 40 target faces, which were presented for 1000 ms each with a 500 ms inter-trial blank white screen.

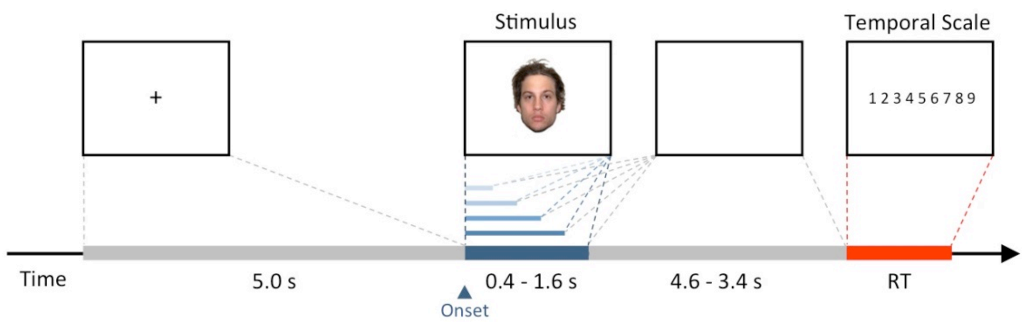

Figure 1. Timeline of the generic single experimental trial.

Temporal task. Participants were first instructed to associate the extremes of a rating scale (1 to 9 points) with a duration of 0.4 s (the shortness duration) and a duration of 1.6 s (the longer duration). Then, they performed 20 training trials with images of objects, with the goal of "calibrating the use of the scale," having to also evaluate with intermediate durations of 0.7, 1.0, and 1.3 s. Each trial began with a cross presented in the middle of the screen lasting 5.0 s followed by the object image (four trials for each duration were randomly presented). After stimulus offset the screen remained blank (i.e., white) until 5.0 s after the stimulus onset. This time lag was necessary in order to access the slow heart rate deceleration response and to avoid EMG contamination by the hand movement in the behavioral response. Then, a prompt with the rating scale was displayed for duration judgments until a response

was made, followed by a 0.5 s inter-trial interval. The same procedure was followed for the test phase, where in two different blocks participants evaluated the duration of a neutral face which was either one of the 40 previously studied faces (i.e., a familiar photo) or one of 40 new faces. Four familiar photos and four new photos were presented for each of the five durations (4 targets x 5 durations). The 40 trials in each of the 2 blocks were presented randomly and encompassed a total of 80 trials. The participants rested for 3 minutes between the two experimental blocks.

Duration judgments. Different indexes were calculated as a function of analysis requirements. For the main analysis, the individual rating scale scores were converted to a temporal metric (i.e., *temporal value = [(score - 1) x 0.15] - 0.4*), in order to facilitate interpretation. In addition, the temporal ratios were also calculated (i.e., *temporal ratio = temporal value / objective duration*) to contrast with physiological deactivation latencies. These indexes were averaged for each experimental condition.

Facial EMG. Using Acqknowledge 4.4 (Biopac Systems Inc., Goleta, CA), fEMG signals for Corrugator Supercilii (CS) and Zygomaticus Major (ZM) muscles were visually inspected for noise, artifacts and anomalous waveforms, and then were filtered offline with a bandpass range of 20-400 Hz (the high-pass filtering at 20 Hz reduce blink, eye movements and other low-frequency artifacts; Van Boxtel, 2001). A 50 Hz notch filter was also applied to reduce power line artifacts.

Then, the filtered signals were rectified, integrated and smoothed over a 20 ms moving window. Next, 100 ms epochs from 1,000 ms pre-stimulus to 5,000 ms after onset were averaged from the filtered signals, creating 60 distinct epochs. The data were then standardized (i.e., transformed to z-scores) within participants and muscle sites, attenuating the impact of highly reactive participants (Tassinary & Cacioppo, 2000). Trials with response errors, artifacts, or electromyographic activation exceeding 5 times the participant's average standard deviation in each muscle within this time window were eliminated. Reported fEMG z-scores are expressed as changes from the average activity in baseline (400 ms to 0 ms), with values greater than 0 representing an increase over stimulus baseline. Short time windows under 500 ms have been used (e.g., Herbert et al., 2009; Neta, Norris, & Whalen, 2009; Oberman, Winkielman, & Ramachadran, 2009). We chose the 400 ms baseline window as a way to minimize the occurrence of excessive artifacts, following a similar strategy adopted by De Vries and collaborators (De Vries, Holland, Chenier, Starr, & Winkielman 2010). Additionally, we also excluded trials in which the variation from baseline exceeded +/- 5 SDs

to reduce the impact of extreme values. Although it led to a high percentage of trials removed (10.3% trials), this strategy was critical because we needed to detect activation (or deactivation) peaks and their latency in order to fulfill the experimental goals. The mean for each design condition as a function of the 50 points in time was estimated for each one of the muscles. According to the predictions of the corrugator muscle responses (i.e., activation time and gradient), 3 indexes were calculated: (1) the mean latency of the onset of the deactivation as an index of activation duration, (2) the amplitude mean during the activation period (until the onset of the deactivation), and (3) the amplitude mean during the period after deactivation (i.e., returning to baseline). The deactivation latency was defined as the time from which there was a continuous decrease in the activity lasting at least 400 ms, operationalized as the largest difference between 4 points (of 100 ms) in the time-course within the 5 second window from the onset of the stimulus. As an index of the EMG gradient we opted for the average corrugator activation amplitude until the onset of the deactivation instead of the amplitude peak since there is a great amount of variability between the time-course epochs. As predicted, the zygomaticus muscle did not show a pattern compatible with an EMG gradient, even a negative one, and did show a greater variability, which impeded the calculation of any of the previous indexes.

Heart Rate. After the exclusion of artifacts, heartbeats per minute (bmp) were derived offline from the ECG signal through an algorithm computing the interval time between successive R-waves. To standardize and baseline correct, we applied the same procedure that we applied to the EMG data. Additionally, for the mean of each condition for the 50 points of HR time course response, we calculated the deceleration amplitude of the HR as an index of attentional orientation and the latency until the maximum deceleration (as an exploratory index of attentional dependence related to the duration of the stimulus). The amplitude of the deceleration of the HR was calculated as the difference between the maximum and minimum values within the window of 4 seconds (from the onset of the stimulus) following Bradley and collaborators (Bradley, Codispoti, Cuthbert, Lang, 2001).

Results

Duration Judgments. Analyses were performed entering each dependent variable in a multifactorial analysis of variance (ANOVA), with stimuli duration, familiarity and experiment block as the within-subject factors.

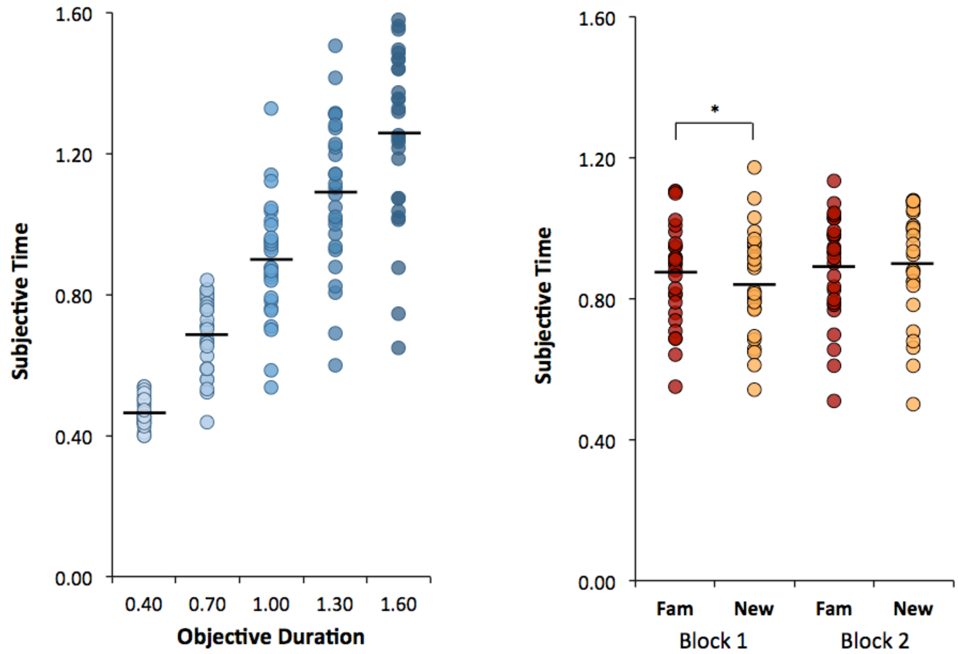

Figure 2. Duration estimation plots in function of objective duration (left panel), and familiarity by block of trials (right panel).

Figure 2 documents that participants were highly sensitive to the stimulus durations. The main effect of time duration, $F(4,104) = 228.89$, $p < .0001$, $\eta^2 = .90$, is almost perfectly (90% of variance) represented by the time linear trend, $t(26) = 16.70$, $p < .0001$, $d = 3.21$. None of the other factors directly or indirectly moderated this duration effect (all interactions had Fs<1). Although there was not a main effect of familiarity on duration estimates, $F(1,26) = .73$, $p = .399$, $\eta^2 = .03$ (M_{Fam}=0.879 s vs M_{Unfam}=) 0.874 s), there was an interaction between familiarity and block, $F(1,26) = 5.12$, $p = .032$, $\eta^2 = .16$. There was evidence of the expected effect of familiarity only in the first block, $t(26) = 2.23$, $p = .035$, $d = .43$ (it dissipated in the second block $t(26) = -1.38$, $p = .18$, $d = .27$, suggesting that the experience of familiarity changed through the task). We also found the expected main effect of block $F(1,26) = 7.77$, $p < .01$, $\eta^2 = .23$, reflecting the fact that durations were overestimated in the first block (0.857 s) in comparison to the second one (0.896 s).

Psychophysiological analysis. For the sake of simplicity, we analyzed the physiologic data only for the experimental conditions where it was clear that an effect was detected in participants' estimations of duration. Thus, the significance of the physiological effects was

tested only for the first block in the case of familiarity and for the whole experiment in the case of the duration of the stimuli. ANOVAs with repeated measures were performed separately for each of the factors adding the time course of the physiological response as a second factor.

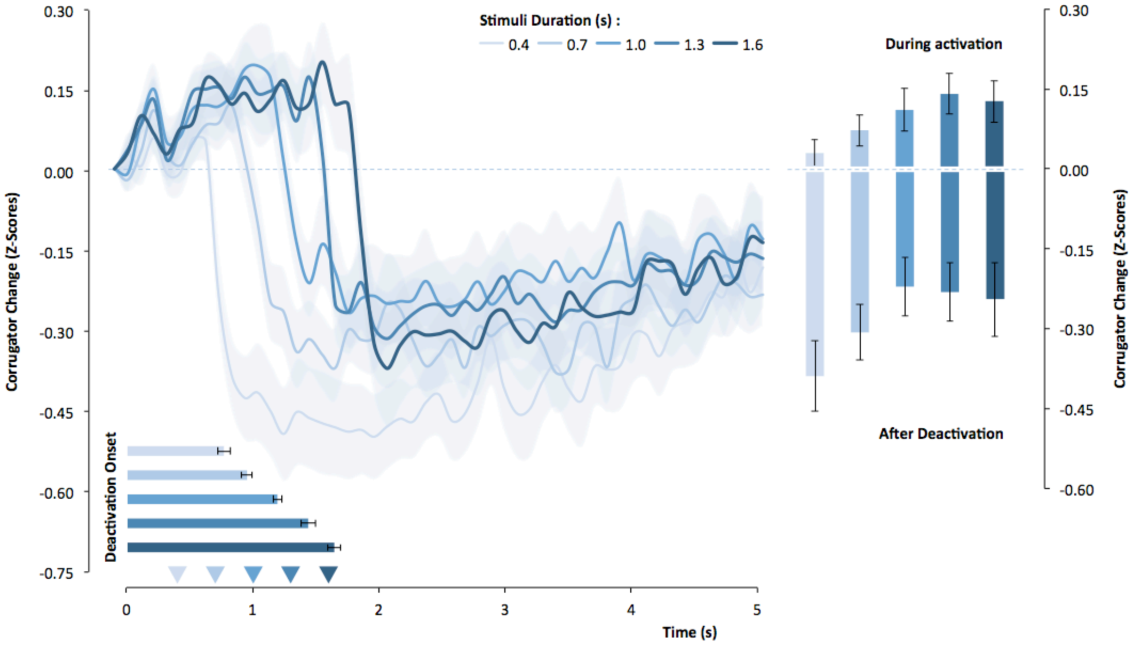

Figure 3. The standardized corrugator supercilii (CS) activity over the course of time as a function of objective duration of the stimulus. The means of CS activity during and after the activation period and the mean latency until muscle deactivation (latency) are represented by the superimposed bars.

CS activity and objective duration effects. As is evident in Figure 3, the CS muscle changed as a function of the stimulus duration, $F(4,104) = 6.164$, $p < .0001$, $\eta^2 = .44$. As the upper panel of Figure 3 illustrates, there is clearly an initial period of activation of the corrugator followed by an abrupt deactivation. This difference in activity across time, $F(49,1274) = 20.22$, $p < .0001$, $\eta^2 = .19$, was modulated by the objective duration of the stimulus, $F(196,5096) = 5.55$, $p < .0001$, $\eta^2 = .176$. To understand how stimulus objective duration modulates the CS activity, we analyzed its effects in deactivation latency and mean amplitude during and after deactivation. As hypothesized, the magnitude of activation differed significantly as a function of the stimulus objective duration, $F(4,104) = 3.02$, $p = .021$, $\eta^2 = .10$, with a positive linear component, $t(26) = 2.83$, $p < .01$, $d = .54$. Statistically, this

difference in CS activity seems to be maintained even after deactivation and the offset of the stimulus, $F(4,104) = 3.04$, $p = .020$, $\eta^2 = .10$, also presenting a linear trend at the limit of significance, $t(26) = 2.05$, $p = .0503$, $d = .395$. As we predicted, the deactivation latency covaries with the objective duration of the stimuli, $F(4,104) = 62.25$, $p < .0001$, $\eta^2 = .705$. The accentuated linear trend is remarkable, $t(26) = 15.05$, $p < .0001$, $d = 2.90$, as seen in the lower graph of the top panel of Figure 3.

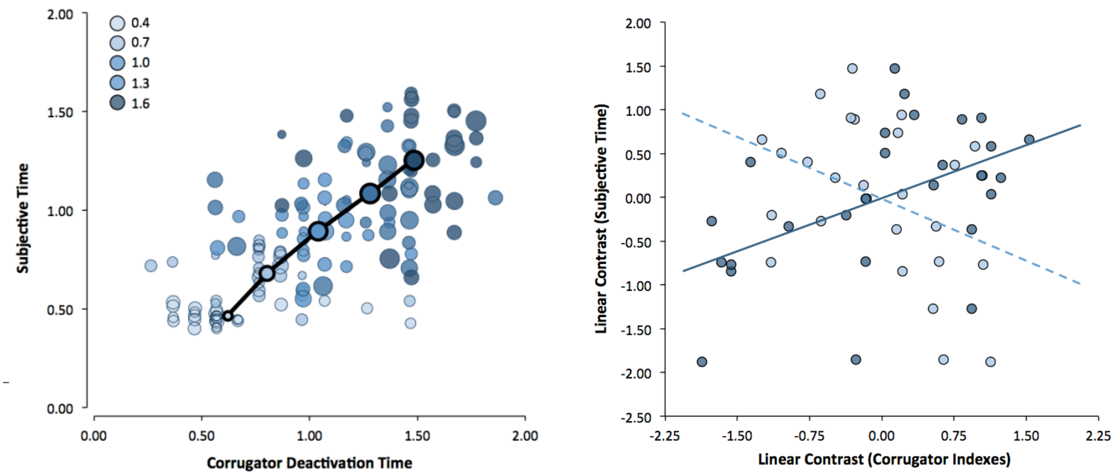

Figure 4. In the left pane group means (black lined circles) and individual means (light circles) of subjective duration as a function of the corrugator deactivation latency are shown. The diameter of the circles represents the amplitude of activation until the corrugator deactivation. In the right pane the correlations (i.e., mediation effect) between subjective duration effect (linear contrast) with both corrugator deactivation latency effect (linear contrast – continuous line) and activation amplitude effect (linear contrast – dashed line) are shown.

CS activity mediation effects. To test whether the corrugator pattern of activity mediates the effect that objective duration has on subjective duration, we followed the within-mediation procedure of Judd, Kenny and McClelland (2001) (with more than two levels). Individual linear trends (in function of objective duration) were computed for the corrugator parameters and subjective duration, using weights of -2, -1, 0, +1, and +2, and performing a regression analysis. As we can observe in Figure 4A, deactivation latency positively predicted the subjective duration estimation, $\beta = .51$, $t(25)=2.95$, $p < .01$. Unexpectedly, the amplitude of the corrugator activity did mediate subjective duration, $\beta = -.44$, $t(25) = -2.46$, $p = .02$, but

in the opposite direction. The same pattern was observed for the amplitude of corrugator activity after deactivation, $\beta = -.42$, $t(25) = -2.32$, $p = .03$.

CS activity and familiarity effects. No effects of familiarity were observed in the CS, $F(1,26) = .03$, $p =. 857$, $\eta^2 = .00$, suggesting familiarity was not manipulating mental effort. The analysis revealed of course the previously detected effect of time (course) in the CS activity, $F(49,1274) = 13.95$, $p < .0001$, $\eta^2 = .35$. This factor did not interact with familiarity either, $F(49,1274) = .76$, $p = .891$, $\eta^2=.03$.

ZM activity and objective duration effects. The activity of this muscle changed over the course of time, $F(49,1274) = 8.34$, $p< .0001$, $\eta^2 = .24$. In Figure 5, there is a clear initial deactivation followed by a slow recovery to baseline over time. The activity of this muscle was not shown to be significantly modulated by the objective duration of the stimulus, $F(4,104) = 1.37$, $p = .250$, $\eta^2 = .05$. Stimulus objective duration seemed, however, to impact the pattern with which the ZM muscle was responding over time, $F(196,5096) = 1.84$, p < .0001, $\eta^2 = .07$. Analyzing the first 2.5 seconds of this muscle activity after the stimulus onset, we were able to detect that its activity was reduced when the stimuli had longer objective durations (a negative linear trend; $t(26) = -1.84$, $p = .083$, $d = .347$).

ZM activity and familiarity effects. A main effect of the familiarity factor, $F(1,26) = 5.57$, $p = .026$, $\eta^2 = .18$, suggests a higher level of activation of this muscle in the familiar conditions (-0.048) than in the unfamiliar conditions (-0.115). This effect was constant over the course of time, due to a non-significant interaction between these two factors, $F(49,1274) = .871$, $p = .723$, $\eta^2 = .03$. As was previously detected, the variation in the ZM over time was also significant, $F(49,1274) = 2.77$, $p = .0001$, $\eta^2 = .10$.

ZM activity mediation effects. To test whether the ZM activity mediates the effect that familiarity had on subjective duration we computed the relationship between the two effects, weighting the familiarity conditions as -1 and +1. The effects of familiarity on the zygomaticus were a good predictor of the bias that familiarity promotes for duration judgments, $\beta = .54$, $t(25) = 3.23$, $p < .01$.

Heart Rate and objective duration effects. The heart-rate response to the face stimuli was deceleratory, beginning shortly after stimulus onset until reaching a minimum several hundred milliseconds after its offset. The 100 ms by 100 ms data are presented in Figure 2 as a function of stimuli objective duration. Heart-rate changed significantly over the course of time, $F(49,1274) = 41.89$, $p < .0001$, $\eta^2 = .617$, and the trend analysis confirmed the

reliability of the deceleration followed by an acceleratory period with a significant quadratic component, $t(26) = 4.45$, $p < .001$, $d = .857$. The heart-rate response itself seems to be determined by the stimulus objective duration $F(1,26) = 3.23$, $p = .015$, $\eta^2 = .15$, which was qualified by time-course, $F(196,5096) = 5.10$, $p < .0001$, $\eta^2 = .17$. This qualification suggests that stimulus objective duration impacts not only the degree of heart-rate response but also the previously observed pattern of that activation. To capture such influence, we calculated a set of new variables represented by the deceleration amplitude, and the latency of the maximum deceleration occurred as a function of the real duration of the stimulus (see Figure 6). Stimuli duration promoted systematic positive related differences in the amplitude of heart-rate deceleration, $F(4,104) = 3.55$, $p < .01$, $\eta^2 = .12$, (the linear component explains the effect; $t(26)=2.24$, $p = .034$, $d = .43$), and a systematic decrease in the time needed to achieve a minimum deceleration, $F(4,104) = 11.796$, $p < .0001$, $\eta^2 = .31$, (the linear component by itself explains the effect, $t(26) = 5.85$, p < .0001, $d = 1.13$).

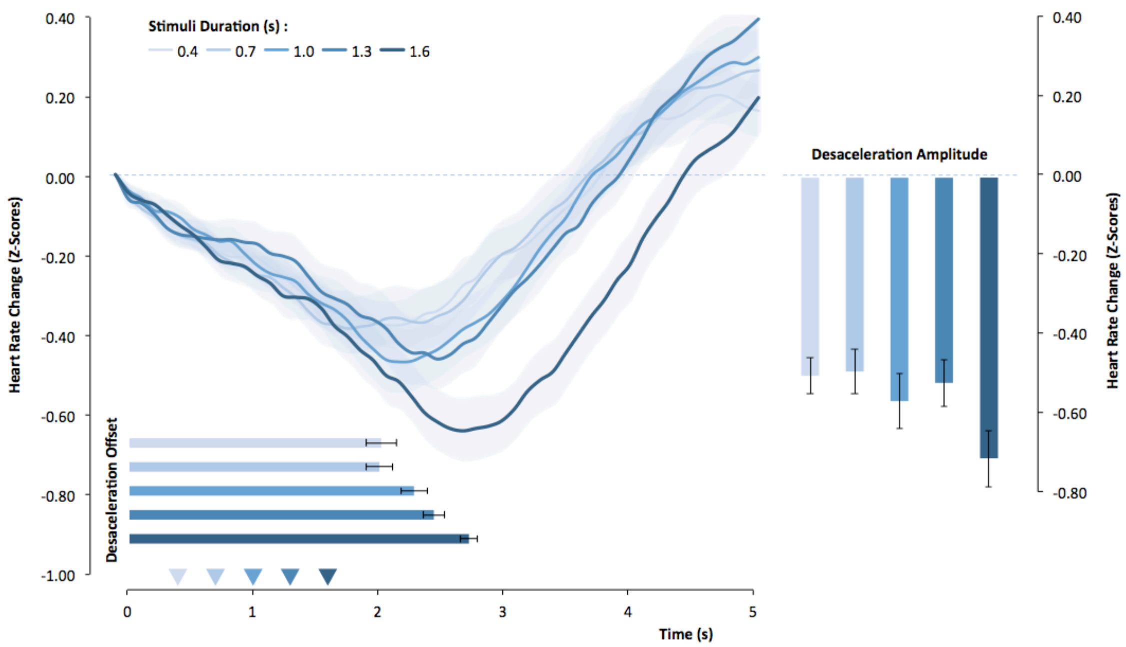

Figure 5. The standardized heart rate response over the course of time as a function of objective duration of the stimulus. The means of HR deceleration amplitude and latency are shown in the superimposed bars.

Heart rate mediation effects. To test predictions from attention-based time perception theories, we examined whether differences in temporal judgments associated with stimulus duration could be predicted by the heart-rate deceleration parameters (see Figure 7). To directly test this, we followed the mediation approach of Judd and collaborators (Judd, Kenny, & McClelland, 2001) in the same way used in the CS mediation effects, using weights of -2, -1, 0, +1, and +2 to compute the heart rate parameters (amplitude and latency) and subjective duration as a function of objective duration. First, the within-subject mediation analysis did not reveal a significant prediction of decelatory amplitude over subjective duration, $\beta = .28$, $t(25) = 1.45$, $p = .159$. Second, we tested whether the latency where the heart rate had its maximum deceleration could be the factor relevant for predicting duration judgments. The relationship between the two trends, $\beta = -.08$, $t(25) = -.42$, $p = .68$, suggested that this may not be the case.

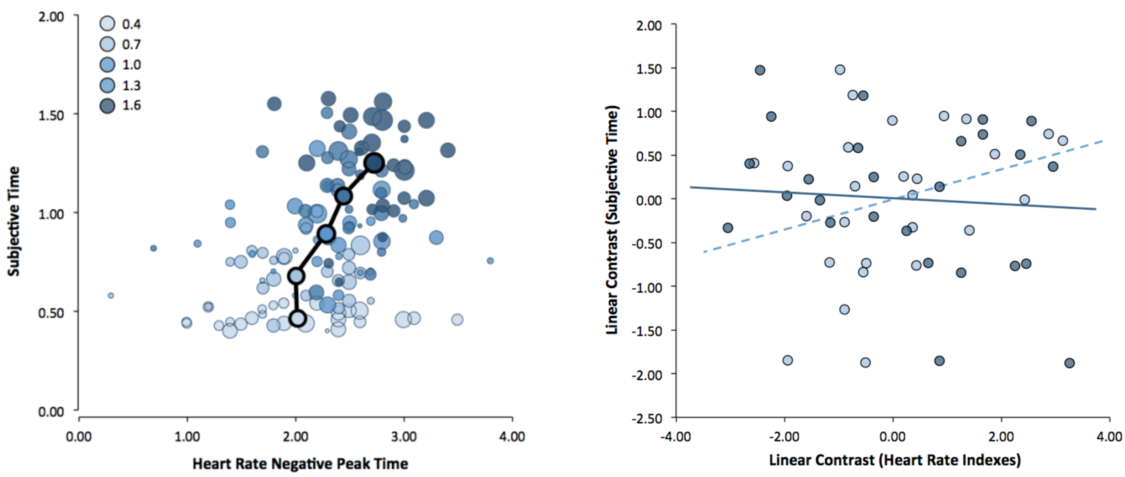

Figure 6. In the left pane the group means (black lined circles) and individual means (light circles) of subjective duration as a function of the heart rate deceleration latency are shown. The diameter of the circles represents the amplitude of deceleration. In the right pane the correlations (i.e., mediation effect) between subjective duration effect (linear contrast) with both HR deactivation latency effect (linear contrast – continuous line) and HR amplitude effect (linear contrast – dashed line) are shown.

Heart Rate and familiarity effects. Heart-rate activity was analyzed only for the first block, where we previously detected an impact of familiarity in bias duration judgments. Using heart rate mean activity as a dependent measure in an ANOVA with familiarity,

duration and time course as the within-participant factors revealed no significant effects of the familiarity factor, $F(1,26) = .820$, $p =. 373$, $\eta^2 = .03$. Only the previously detected impact of duration was detected, $F(49,1274) = 31.89$, $p < .0001$, $\eta^2 = .551$, which was not moderated by the familiarity factor, $F(49,1274) = .318$, $p =. 999$, $\eta^2 = .01$.

Discussion

The results show that objective duration is correlated with the dynamic activity of the corrugator supercilii and that this relationship mediates subjective judgments of duration. Although several authors have stated that motor areas (e.g., SMA) could be involved in building up a representation of time (Coull, Vidal, & Burle, 2016; Nobre & O'Reilly 2004), raising the possibility of implicit motor timing (Merchant & Yarrow, 2016), these results are the first empirical evidence of this. Explicit perceptual timing is shown to have a relation with (spontaneous) motor output. Namely, our data show that amplitude of corrugator activation and the duration of that activation are both indexes that show a climbing activity: a) similar to one verified in the SMA and in the Insular cortex; b) similar to the EMG gradients shown in sustained attention and c) are both correlated with objective duration.

Replicating previous studies (Meissner & Wittmann, 2011; Otten et al., 2015), but with very short durations, the heart-rate deceleration response (amplitude and latency) was determined by the stimulus objective duration. However, that correlation does not explain subjective time experiences as the corrugator supercilii does. Importantly, our results with the corrugator cannot be an artifact promoted by the preparation of the motor response since motor response is only offered with seconds of delay (Kononowicz, van Rijn, & Meck, 2016). Future studies should address the mechanism that is associated with this muscle activity (e.g., sustained attention, muscle feedback, muscle properties, etc.).

Only the zygomaticus major was sensitive to familiarity effects over duration estimates. Previous exposure promotes fluency of processing and thus a subjective experience of ease that elicits judgments of positive affect (e.g. Garcia-Marques, Mackie, & Claypool, & Garcia-Marques 2010; Garcia-Marques, Prada, & Mackie, 2016) indexed by the activation of the zygomaticus major muscle (e.g. Harmon-Jones & Allen, 2001; Winkielman & Cacioppo, 2001), which is responsible for smiling and positive affect (Cacioppo et al., 1986; Dimberg et al., 2000). However, the activation of the corrugator seems more likely to signal disfluency (Topolinky & Strack, 2015), which was not promoted in our experiment.

Thus, whereas the zygomaticus major is related to the bias promoted over duration judgments, its activation is unrelated both with duration and with the subjective experiences of duration. This result is at odds with our expectation given its low percentage of Type I slow-twitch extrafusal fibers. Also, the lack of correlation clearly suggests that duration is not an "*affective judgment*".

These data directly support embodiment theories suggesting that judgments rely on interoceptive states, including sensorimotor and affective systems (e.g., Barsalou, 2008; Niedenthal, 2007; Winkielman, Knutson, Paulus, & Trujillo, 2007). The idea that the experience of time could be based on somatic components of feelings of effort related to sustained attention has old speculative roots (Mach, 1890/1897; Guyau, 1890; Münsterberg, 1889; Marchetti, 2009), but now has empirical support, which is in line with different neurophysiological evidence (Craig, 2009a, 2015; Wittmann, 2013, 2009).

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Secção III

Discussão Geral

Discussão Geral

Os trabalhos desenvolvidos nesta tese tiveram como principal objectivo contrastar as duas explicações teóricas do efeito de familiaridade em julgamentos de duração propostas na literatura, mas até aqui sem fundamentação empírica. Nomeadamente, uma hipótese atencional, enquadrada em modelos dedicados de processamento de informação (i.e., relógio-interno) no campo da perceção de tempo, e uma hipótese atribucional de fluência, enquadrada em modelos generalistas de decisão e julgamento.

A meta-análise realizada (primeiro artigo) integra quantitativamente toda a literatura referente ao efeito de familiaridade e permite claramente defini-lo como fiável com uma magnitude média (g_{Hedges} = .52).

Nesta meta-análise definimos como possíveis moderadores do efeito de familiaridade previstos pelos modelos de relógio-interno, variáveis que informam sobre diferentes processos atencionais críticos na monitorização do tempo. Nomeadamente, ao nível da capacidade e distribuição de recursos atencionais (possivelmente de funções executivas controladas), e processos de interferência (exógena) na atenção seletiva (em fases iniciais e tardias do processamento automático do estímulo). Os resultados sugerem que não existe evidência de que o efeito da familiaridade seja dependente da distribuição explícita dos recursos atencionais alocados entre as características temporais e não temporais do estímulo. Assim não existe suporte para a abordagem teórica da sensibilidade de efeitos de capacidade no monitoramento do tempo (Brown, 2008; Block & Zakay 1996; Block et al., 2010). No entanto a hipótese atencional ganha relevo, quando levamos em consideramos outro tipo de efeitos. Verificamos um "*efeito de slope*", isto é, um incremento do efeito de familiaridade em função da duração objectiva. Este efeito permite demonstrar a existência de processos tardios de interferência na atenção seletiva sustentada (Buhusi & Meck, 2006, 2009; Zakay & Brown, 1997), embora seja inclusivo quanto a efeitos atencionais em fases iniciais do processamento (Enns, et al., 1999; Lejeune, 1998; Mattes & Ulrich, 1998). Este facto sugere a relevância dos mecanismos atencionais não apenas para a perceção de tempo, mas para o efeito de familiaridade observado.

Os dados obtidos permitem igualmente corroborar algumas hipóteses derivadas dos modelos julgamento. Primeiro, o efeito de familiaridade ocorre quando apenas a fluência

perceptiva é manipulada, como esperado por estes modelos atribucionais. Segundo como esperado por estas abordagens o impacto da familiaridade ocorre essencialmente quando existe ambiguidade da informação temporal. Os dados sugerem que os efeitos da familiaridade/fluência ocorrem quando a informação temporal é mais difícil de discriminar, o que está concordante com o uso metacognitivo da experiência de fluência para desambiguar (erroneamente, i.e., com falsa atribuição) a informação do julgamento corrente (e.g., Dechêne et al., 2010; Gomez & Robertson, 1979; Novemsky et al., 2007; Unkelbach, 2007).

Mas a moderação do efeito de familiaridade/fluência por variáveis associadas a diferentes pressupostos do modelo atribucional da fluência, nomeadamente, a hipótese de discrepância (requerida para a fluência experienciada), e a hipótese da "*discounting*" (correção do alvo da atribuição) não parece ser homogénea para as manipulações de fluência preceptiva e familiaridade.

Os dados sugerem que a fluência é uma experiência que assenta na discrepância de fluência pelo efeito ser sensível a diferentes moderadores abordando a distribuição contextual de estímulos entre ensaios. Um favorecimento das comparações contextuais, ou diminuição da expectativa experiencial de fluência, promove um aumento do nível de fluência e uma consequente ampliação do efeito de fluência (Whittlesea & Leboe, 2003). Contudo os dados são apenas claros quando a manipulação é de fluência perceptiva. Não encontramos evidência da hipótese de discrepância para manipulações de familiaridade. Igualmente não se deteta evidências de "*discounting*" nas manipulações de familiaridade, Detecta-se o efeito de "*discounting*" nos estudos que manipularam fluência perceptiva, dado que as análises com o recurso a moderadores que atestam a (probabilidade de) deteção da verdadeira fonte de fluência (i.e., duração do estímulo e avaliação de informação relacionada com a fonte de fluência), sugerem o envolvimento deste tipo de processos de correção. Tal como se esperava as condições que levaram os indivíduos a reconhecer a verdadeira fonte de fluência pudessem ativar o processo de correção ou "*discounting*" (Oppenheimer, 2003; Schwarz & Clore, 2007; Whittlesea & Williams, 1998).

Porquê desta dissociação entre familiaridade e fluência perceptiva? Note-se em primeiro lugar que a hipótese de discrepância tem especial relevo numa comparação que não foi possível ser executada com os estudos que manipularam familiaridade. Trata-se da comparação entre manipulações da familiaridade within versus between (i.e., heterogeneidade versus homogeneidade de contexto). Este é o moderador para o qual existe mais evidência e que mais suporte para a hipótese de discrepância, com manipulações de familiaridade

(Bornstein, 1989; Dechêne et al. (2010). Os outros moderadores foram inferidos com base em estudos que fazem variar a distribuição dos níveis de fluência ao longo dos ensaios. É assim possível que estas condições não fossem as ideais para testar os efeitos de familiaridade. Além de que os dados podem apenas estar a sugerir que as manipulações que afectam a discrepância são mais relevantes para a fluência porque a familiaridade pode estar já associada a níveis mais elevados de fluência e então manifestar efeitos de tecto. O facto da fluência percetiva ser mais sensível a efeitos de "*discounting*" pode sugerir que o processo atribucional que lhe subjaz é mais sensível a esses efeitos. Uma hipótese disto ocorrer é se pensarmos que os efeitos da fluência percetiva são eles próprios dependentes de uma atribuição de fluência à familiaridade (Garcia-Marques et al, 2013). Outra hipótese é a de que existe uma diferença de saliência da fonte de fluência. Enquanto o tamanho de um estímulo que manipula fluência é detetado online, a deteção de apresentação prévia é dependente de processos e memória que podem necessitar de condições outras para serem instaurados. Por último é de salientar que quer a discrepância e "*discounting*" são duas hipóteses que definem as condições que se postulam ser necessária para experienciar diferenças de níveis de fluência no processamento. Elas não definem a hipótese atribucional per si.

Em resumo, os dados da meta-analise deixam claro que o efeito de familiaridade pode advir de processos atribucionais e não apenas dependentes de questões atencionais.

Corroborando a hipótese atencional, os dados do segundo artigo demonstram que a os efeitos da familiaridade em julgamentos de duração também se estendem à sensibilidade ou discriminação temporal, o que apenas é previsível por interferências atencionais (mas não atribucionais). Os modelos de relógio-interno tipo "*pacemaker-accumulator*" prevêem que efeitos de variabilidade na deteção da informação temporal (i.e., latências da operação do "*switch*") sejam o reflexo da sensibilidade temporal (Block et al., 2010; Brown, 1997; Macar, et al., 1994). Uma explicação metacognitiva baseada em sentimentos de fluência provenientes de outras fontes, não pode explicar efeitos ao nível da deteção e processamento de informação (temporal) para a qual não tem qualquer valor informativo objectivo.

Mas o terceiro artigo torna claro que se devemos atender a processos atencionais para definir o mecanismo de perceção de tempo, devemos atender aos processos metacognitivos associados à experiência de fluência quando explicamos os efeitos de familiaridade. Os indicadores fisiológicos complementares, um de atenção (i.e., atividade muscular do corrugador superciliar e variações do ritmo cardíaco) e outro de cariz afetivo associado à fluência (i.e., atividade muscular do zigomático major), sugerem uma dissociação de

processos, em que os indicadores atencionais apenas medeiam as estimativas das durações mas não os enviesamentos na duração subjetiva promovidos pela familiaridade. Por outro lado, a atividade do zigomático major, associada ao afeto positivo, apenas mediou os efeitos da familiaridade, mas não a deteção da informação temporal, sugerindo uma explicação atribucional em detrimento de uma explicação atencional.

Globalmente, os dados destas 3 investigações sugerem que ambos os processos inferidos pelos modelos mencionados têm validade explicativa, contribuindo para o efeito de familiaridade nos julgamentos de duração. A familiaridade de um estímulo induz alterações de eficiência de processamento que parecem explicar os efeitos da familiaridade na perceção temporal, embora o faça por processos que se sustentam em vias diferentes, no modo como afecta as estimativas e os julgamentos de duração. As evidências aqui encontradas sugerem que a eficiência de processamento associada à familiaridade modela a deteção e estimativa da informação temporal como postulado pelos modelos de relógio-interno (ver Chastain & Ferraro, 1997, Hochhaus et al., 1991, Warm & McCray, 1969). Paralelamente, estes dados sugerem também que a experiência de fluência desse processamento possa ser utilizada meta-cognitivamente no processo decisional do julgamento temporal (ver Kleider & Goldinger, 2004, Masson e Caldwell, 1998; Reber et al., 2004).

Um segundo objectivo desta tese focou o contraste entre os efeitos nos julgamentos de duração obtidos por manipulação de familiaridade versus fluência perceptiva. Na nossa meta-análise (primeiro artigo) contrastámos o efeito dos diferentes moderadores mencionados para os dois tipos de manipulação de fluência: familiaridade (também associada a fluência conceptual) e perceptiva. Uma explicação dos efeitos de familiaridade apenas com base em fluência pressupõe efeitos similares para manipulações puramente de fluência perceptiva, o que, como já referido acima, não se verificou. Ao contrário da familiaridade, todos os indicadores referentes a cada um dos subprocessos associados à atenção e à hipótese de atribuição de fluência foram suportados com exceção do moderador de capacidade. Esta discrepância sugere também que a familiaridade pode exercer papéis distintos da fluência perceptiva (ver Silva, Garcia-Marques & Mello, 2015; Garcia-Marques, Silva & Mello, 2016), contrastando com a ideia veiculada na literatura de que a experiência de fluência exerce efeitos semelhantes sobre os julgamentos, independentemente da sua fonte e nível de processamento (e.g., Alter & Oppenheimer, Reber, Wurtz, & Zimmermann, 2004, Schwarz, 2004).

Adicionalmente, este trabalho procurou contrastar os efeitos de diferentes tipos de repetição, uma vez que a familiaridade encontra-se associada à experiência de reprocessamento do estímulo. Podemos afirmar que não só a repetição feita dentro da tarefa de estimativa temporal (repetição intra-ensaio ou inter-ensaio) como também o *repetition-priming* (estimativas de duração de um estímulo primado por ele mesmo) promove efeitos que são opostos ao efeito da familiaridade em julgamentos de duração. A manipulação de repetição é geralmente relatada como sendo apenas mais uma manipulação da fluência perceptiva (Jacoby, 1991, Jacoby & Witherspoon, 1982). No entanto, esta manipulação clara difere de outro conjunto de manipulações de fluência em seu impacto sobre as estimativas de duração. Estes resultados apontaram para um terceiro efeito moderando a perceção do tempo e os julgamentos de duração. Tal pode vir a pedir uma raiz teórica extra para explorar os mecanismos subjacentes dos efeitos não-temporais na perceção do tempo, que vão para lá de uma explicação de fluência (mas ver Huber et al., 2008) e de uma explicação atencional (mas ver Matthews et al., 2014). Isto porque apesar de se poder pensar que a apresentação homogénea dos estímulos repetidos poder não suscitar níveis de fluência esperados (e haver mesmo mecanismos de inibição de fluência), o que seria uma explicação ao nível da hipótese de discrepância, a verdade é que tal muito dificilmente explica a inversão de efeitos, pelo menos só por si. A hipótese da inversão do efeito se dever a efeitos de "*discounting*" e sobre-correção fica comprometida se pensarmos que este processo pode ser dependente de recuses cognitivos aqui não ativados. É assim um tópico que merece futura analise e discussão dentro de diferentes modelos que explicam fenómenos de ativação e inibição.

Aspectos de integração dos dois modelos

Com esta tese ao estabelecer uma relação entre os efeitos de familiaridade obtidos em duas áreas de investigação distintas, abrimos uma porta para melhor esclarecer os efeitos da familiaridade nos modelos de tempo. Mostramos como existem vantagens em estes modelos não se isolarem das abordagens integrativas realizadas sobre a cognição de julgamento. Apontamos portanto para a necessidade de uma complementaridade dos modelos na compreensão dos processos subjacentes ao efeito da familiaridade que até agora não tinha sido realçado na literatura, particularmente para a necessidade de uma revisão dos modelos de processamento de informação (IP) adoptados no campo da perceção temporal. Este campo de estudo, talvez pela especificidade dos processos implícitos e explícitos de representação do tempo, e da tradição da psicofísica sustentada no comportamento animal (Matthews & Meck,

2014), tem ficado muito isolado de outros campos da psicologia (para uma proposta inter-paradigmática ver Matthews & Meck, 2016). Embora existam alguns modelos integrativos (ver Taatgen, van Rijn, & Anderson, 2007), processos atribucionais têm sido negligenciados como um meio de enviesar julgamentos temporais.

Nesta tese queremos deixar claro que consideramos que os processos atribucionais não são incompatíveis com os modelos IP dominantes, nomeadamente o SET (Gibbon, Church, & Meck, 1984) e o AGM (Zakay & Block, 1996). O SET integra um módulo de decisão que compreende um processo referencial de memória temporal. Pelo que é possível que os processos de estimativas de tempo se sobreponha um processo de julgamento com vista aos indivíduos terem consciência do tempo.

Os modelos IP, percebem o julgamento de duração como relativo a um *standard* previamente registado na memória. Os modelos pressupõem um processo de decisão que consiste na comparação entre essa representação temporal na memória de trabalho – a duração corrente – e as representações armazenadas anteriores de duração (isto é, a memória de referência). Pressupostos semelhantes são patentes nas abordagens atribucionais como temos vindo a salientar ao longo desta tese. Também para outros tipos de julgamento, a informação contextual pode ser utilizada de modo referencial (Kahneman & Tversky, 1973; Schachter & Singer, 1962; Schwartz, 2004) e tal parece ser o caso dos julgamentos que envolvem sentimentos de familiaridade ou fluência (Reber, et al., 2004; Schwarz, 2004). Os próprios sentimentos têm assim uma natureza relativa (hipótese de discrepância; Whittlesea & Leboe, 2003). Assim o sentimento proveniente da fluência de processamento tendo um valor informativo relativo à duração (Reber et al., 1998; Winkielman & Cacioppo, 2001; Forster et al., 2015, 2016), fornece a informação "relativa" já pressuposta pelos modelos do relógio-interno.

Os modelos de julgamento têm sugerido que quando a dificuldade do julgamento é grande, pela ambiguidade da informação recebida ou falta de recurso cognitivos, a probabilidade do uso da fluência é maior (Dechêne et al., 2010; Novemsky, Dhar, Schwarz, & Simonson, 2007; Unkelbach, 2007). Assim tal como os nossos dados da meta-análise sugerem, é possível que a discrepância reduzida entre o *standard* de comparação e a representação temporal corrente (resultado do processo de monitorização na fase relógio), dê mais destaque ao uso da fluência. Um outro alicerce que sustenta a implementação do uso da fluência, é se o seu valor ecológico (e.g., a fluência informa duração) pode ser confundido com o sinal (i.e., informação temporal). Vários estudos têm demonstrado que a fluência

experienciada é proporcional à duração do estímulo (Reber et al., 1998; Winkielman & Cacioppo, 2001; Forster et al., 2015, 2016), e por isso, é possível que esse sinal possa ser adicionado ou integrado na representação temporal, na própria fase da acumulação, ou na memória de trabalho, que é continuamente atualizada ao longo do intervalo a estimar. Por uma ou por outra via, uma previsão da atribuição da fluência, é ser mais provável de ocorrer quando a duração objetiva é muito curta, pois o processo de deteção de informação temporal vai se "confundir" com o próprio processo de julgamento. Em conformidade, os dados da meta-análise sugerem efeitos de fluência maiores para durações mais curtas, independentes das diferenças relativas entre as durações utilizadas dentro dos estudos (i.e., indicadores de ambiguidade temporal).

Questões em aberto e futuras Direções

Com os dados desta tese consideramos que fornecemos uma nova visão do efeito de familiaridade, que fornece direção e abre portas a um conjunto de questões a serem abordadas em futuros estudos empíricos

Uma destas questões associa-se aos efeitos nulos encontrados na meta-analise. Até agora temos interpretado esses efeitos nulos de alguns dos indicadores como não suportando as hipóteses derivadas dos pressupostos dos modelos. No entanto o não suporte não é a sua invalidação. Nenhum dos moderadores que testamos foi contrário às nossas hipóteses e dados nulos podem ser explicado por várias razões como por exemplo a falta de potência de teste. Por exemplo, na meta-analise temos evidências de processos atribucionais suportados pela moderação da ambiguidade temporal, que converge com a mediação de afectos positivos associados à fluência (i.e., atividade do zigomático major) no efeito de familiaridade. O processo de "*discounting*" só ocorre se existiram as condições para a atribuição se estabelecer. E os nossos dados sustentam que em condições de ambiguidade o efeito tem maior magnitude. Mas para existir correcção um outro pressuposto tem de ser adicionado, que é a consciência dessa atribuição errónea. Deste modo, o pressuposto de uma correção ("*discounting*") não é necessário à definição do efeito como um processo adicional, apesar de o corroborar. Assim a sua não sustentação nos dados não invalida a atribuição da fluência ao julgamento da duração. Da mesma forma, na meta-analise não encontramos evidências de efeitos de capacidade, mas no segundo estudo encontramos efeitos da familiaridade na discriminação temporal, que são encontrados sobretudo em estudos que manipulam capacidade (Block et al., 2010; Brown, 1997; Macar et al., 1994). É assim de extrema

relevância que todos estes dado seja esclarecidos e que com base nestes dados se realizem novos e mais direcionados estudos controlando experimentalmente as variáveis moderadoras analisadas na meta-análise de forma a clarificar os efeitos nulos encontrados.

Por exemplo, para esclarecer porque a divisão de recursos (i.e., tarefa concorrente) que podem ser necessários para manter a atenção seletiva ao tempo, não moderou o efeito de duração de familiaridade, estudos futuros devem manipular a presença de uma tarefa concorrente no mesmo desenho experimental. Por exemplo, podemos seguir o paradigma experimental utilizado por Macar et al. (1994, 2004) manipulando a familiaridade. Outro processo a esclarecer são os efeitos de "*discounting*" que são apenas detectados em manipulações de fluência perceptiva. Estudos futuros devem testar diretamente no mesmo estudo usando, por exemplo, o paradigma experimental usado por Bornstein e D'Agostino (1994) ou por Schwarz (1998, Schwarz et al., 1998), que tornam a fonte da fluência altamente explícita para os participantes.

Adicionalmente, nesta tese foram deduzidas dos modelos algumas hipóteses para serem testadas. Mas nem todas elas, e nem todos os pressupostos subjacentes a estes modelos foram capazes de ser abordados meta-analiticamente, nem o foram experimentalmente. Assim estas novas hipóteses devem ser abordadas experimentalmente. Por exemplo, não foi possível testar diretamente o efeito de "*intercept*" (mostrando um enviesamento promovido pela deteção inicial das propriedades "*low-level*" do estímulo). Este aspecto particular subentende o processo dinâmico do processamento dos estímulos, o curso dos vários processos atencionais que são moderados pela familiaridade, e essa interação com a própria monitorização do tempo que se desenrola no tempo. O curso do processamento das características não-temporais não é independente da duração, e por isso, os efeitos da familiaridade devem ter em conta esta relação que destacamos neste trabalho mas que necessita de mais dados empíricos para a validar. Para o efeito devem ser utilizados paradigmas experimentais que possibilitem o recurso a medidas continuas (e.g., eye-tracking; Althoff & Cohen, 1999, Hsiao & Cottrell, 2008; ou ERPs; Friederici, 2002; Hagoort, 2008), ou que utilizem procedimentos de interferência atencional em momentos específicos no tempo (i.e., Buhusi & Meck, 2006, 2009).

Os nossos dados não permitem determinar com clareza quais os processos que explicam as diferenças entre manipulações perceptivas e conceptuais. Futuros estudos poderão abordar novas hipóteses que permitem perceber essa dissociação. Por exemplo os estudos poderão focar os aspectos da dinâmica de processamento, que podem ser uma das

razões pela qual manipulações de fluência conceptual e perceptiva são moderadas diferencialmente por variáveis que envolve uma dependência da duração objectiva, tais como os efeitos de "*slope*" (i.e., atenção seletiva) e efeitos da ordem de magnitude da duração (i.e., indicador de "*discounting*"). Como referido, o processamento dos aspectos perceptivos "*low-level*" acontece em fases iniciais, enquanto os aspectos conceptuais "*high-level*" são processados em fases mais tardias, havendo consequentemente impactos diferenciais em função da duração do estímulo.

Estudos sobre o "efeito de verdade" mostram que a fluência conceptual é mais relevante para o efeito da repetição do que a fluência perceptiva (Silva, Garcia-Marques & Mello, 2015; Garcia-Marques, Silva & Mello, 2016; Parks & Toth, 2006), possivelmente por ser a apropriada fonte de fluência para esse tipo de julgamentos que ancoram no significado (Whittlesea, 1993). Nesse sentido, não podemos descartar a hipótese de que o tipo de fluência possa ter diferente valor informativo nos julgamentos de duração. Futuros estudos poderão explorar esta questão, por exemplo, manipulando a familiaridade através da repetição de aspectos perceptivos em contraste com aspectos conceptuais.

Para entender melhor o real valor diagnóstico da familiaridade com relação aos julgamentos de duração, estudos futuros poderiam abordar a bidirecionalidade da associação familiaridade-duração (Garcia-Marques, Mackie, Claypool, & Garcia- Marques, 2004; Converse, Sackett, Meyvis, Nelson, & Sackett, 2010) e avaliar a relação entre as medidas de perceção do tempo e as medidas de fluência entre os diferentes níveis de duração (Reber et al., 1998; Forster et al, 2015). Este aspecto pode ajudar a clarificar os nossos dados electromiográficos, uma vez que a atividade do zigomático major, que sinaliza o afecto positivo associado à fluência, apenas explicou o efeito da familiaridade nos julgamento de duração, mas não a duração propriamente dita. Isto contrasta com os dados de avaliação de fluência ou agradabilidade e que sugerem variar linearmente com a duração (Reber et al., 1998; Forster et al, 2015). Contudo grandes diferenças metodológicas são de destacar. Nestes estudos foram feitos julgamentos afetivos explícitos (que torna mais saliente a componente afetiva) mas não de duração (que é uma tarefa exigente em termos de recursos atencionais). Futuros estudos devem procurar explorar esta inconsistência controlando para estas diferenças.

Contudo o nosso estudo de electromiografia abre uma porta para que o processo de monitorização da informação temporal seja ele mesmo baseado em sensações somáticas e afetos que emergem a partir de um processo interoceptivo (e.g., Barsalou, 2008; Niedenthal,

2006; Winkielman, Knutson, Paulus, & Trujillo, 2007). Os efeitos mediadores da atividade do corrugador nos julgamentos de duração têm uma magnitude muito elevada para poder se descartar essa hipótese. O campo da perceção de tempo ainda não tem uma explicação para o modo como "acedemos" explicitamente a uma representação de duração (Wittmann, 2013). A sensação somática pode ser uma possível via para este processo, e deste modo, a perceção de tempo (explicita) ser baseada em sentimentos. Esta é uma proposta arrojada que deverá ter os devidos desenvolvimentos, e é concordante, com os processos atribucionais de fluência aqui discutidos. Embora se deva uma perspectiva de integração de várias componentes somáticas e afetivas, tal como é postulado pelos modelos interoceptivos multimodais (Craig, 2009, 2015).

Conclusão

Embora muitas questões continuem em aberto, frisando a necessidade de futura investigação, consideramos que os estudos presentes nesta tese contribuem para a compreensão dos mecanismos subjacentes ao efeito da familiaridade nos julgamentos de duração. Ao integrarmos meta-analiticamente toda a literatura empírica sobre o efeito de familiaridade, oferecemos um ponto de referência para futura investigação sobre o tópico, que nós mesmo já iniciámos com dois estudos empíricos. Fica claro nesta tese que ambos os processos atencionais e de atribuição de fluência subjazem os efeitos da familiaridade nos julgamentos de duração, embora os subprocessos, e a dinâmica temporal, através dos quais estas influências são implantadas, requerem contudo mais investigação empírica.

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Seção IV

Anexos

Anexo A: Artigo de Revisão

Ilusões temporais: Paradigma experimental

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Resumo

Neste artigo apresentamos o paradigma base subjacente ao estudo das ilusões temporais (i.e., sobrestimativas ou subestimativas da duração de estímulos ou eventos) promovidas por características não-temporais. É aqui descrito em detalhe o procedimento experimental para induzir este tipo de efeitos, sendo também descritas variações relevantes no paradigma, variáveis moderadoras identificadas na literatura e as teorias com poder explicativo mais abrangente para a maioria das ilusões temporais referidas.

67 p.

Palavras-chave: Duração; ilusões temporais; paradigma experimental; percepção temporal.

Abstract

This article presents the paradigm underlying the study of temporal illusions (i.e., overestimation or underestimation of the duration of stimuli or events) promoted by non-temporal characteristics. It is here described in detail the experimental procedure for inducing such effects, relevant variations of the paradigm, moderating variables and theories with wider explanatory power for most temporal illusion herein presented.

58 w.

Keywords: Duration; experimental paradigm; temporal illusions; time perception.

Ilusões temporais: Paradigma experimental

Introdução

Enquanto o tempo objectivo (físico) avança linearmente em unidades constantes, a experiência subjectiva do tempo pode ser dramaticamente alterada. Intervalos de tempo com durações idênticas não são sempre percebidos como equivalentes na sua duração subjectiva, podendo estas alterações, comumente referidas como ilusões temporais[4], ser sistematicamente induzidas por diferentes características do estímulo (ou do contexto de apresentação). Um exemplo de ilusão temporal é a promovida pelo facto dos intervalos de tempo a serem estimados terem ou não um conteúdo (i.e., são ou não preenchidos). Os intervalos com conteúdo são percebidos como mais longos do que aqueles sem conteúdo (i.e., vazios). Esta ilusão é conhecida por ilusão de preenchimento (‘filled illusion’) e foi demonstrada pela primeira vez nos trabalhos de Hall e Jastrow (1886, ver também Craig, 1973; Curtis, 1916; Droit-Volet, 2008; Fraisse, 1961; Hall & Jastrow, 1886; Israeli, 1930; Mitsudo, Gagnon, Takeichi, & Grondin, 2012; Thomas & Brown, 1974).

O estabelecimento do efeito: Os estudos originais

Karl Vierordt (1868) e alguns dos seus alunos (e.g., Höring, 1864) realizaram alguns dos primeiros estudos experimentais no campo da percepção de tempo. O autor ficou conhecido por defenir a ‘Lei de Vierordt’, a proposição de que durações curtas são julgadas como mais longas, enquanto durações longas são julgadas como mais curtas. No estudo deste fenómeno, que se refere a uma distorção relativa ao tempo objectivo (físico), os dados sugeriram que distorções relativas eram tanto promovidas pelas condições de apresentação dos estímulos, como pelas características dos próprios estímulos moderando este efeito (Höring, 1864; Vierordt, 1868). No seu seguimento, outros autores corroboraram estas evidências estabelecendo as primeiras ilusões temporais, i.e., sobrestimativas ou

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[4] Salienta-se que o estudo da percepção de tempo não se limita ao estudo das estimativas de duração e suas distorções (i.e., ilusões temporais), que neste trabalho abordamos. Outras características temporais como simultaneidade, sucessividade, ordem temporal, ritmo, velocidade do fluxo do tempo, são igualmente estudadas neste campo, dimensões em que várias ilusões igualmente têm sido descritas; como por exemplo a ilusão de “relógio parado” (um exemplo de percepção de velocidade de fluxo do tempo) que consiste no seguinte fenómeno: no primeiro olhar, o ponteiro dos segundos parece momentaneamente parar antes de continuar a contar os segundos a um ritmo normal (e.g., Yarrow, Haggard, Heal, Brown, & Rothwell, 2001).

subestimativas sistemáticas dos julgamentos (prospectivos[5]) de duração para diferentes níveis ou magnitudes de um factor (as quais retratamos neste artigo). Provavelmente o primeiro a fazê-lo foi Volkmar Estel que em 1883 descobriu que a duração percebida de um intervalo é alterada pela duração objectiva do(s) intervalo(s) apresentado(s) anteriormente, ilusão mais tarde denominada por erro de ordem temporal. Seguiram-se outros estudos pioneiros que destacamos: o de Stanley Hall e Joseph Jastrow (1886) demonstrando a ilusão de preenchimento (já mencionada anteriormente); e o estudo de Michael Ejner que 3 anos depois (1889) verifica que a distração da atenção, noutra tarefa não-temporal (e.g., realização de problemas aritméticos) durante o intervalo de tempo em causa, promove uma subestimativa da sua duração (i.e., ilusão 'atencional').

Definição do paradigma base (quadro resumo metodológico)

De modo genérico muitos dos estudos pioneiros, e outros mais recentes em que empreenderam mais rigor metodológico, sustentam-se num paradigma base que neste artigo retratamos: através da manipulação de duas variáveis independentes, uma variável (habitualmente não-temporal) manipulada através das características dos estímulos (ou eventos) cuja duração objectiva (que é variável) é alvo do julgamento temporal subjectivo.

Participantes

Os efeitos de ilusão temporal apresentam magnitudes variadas em função das características não- temporais dos estímulos (ou eventos) que as qualificam. Devido à falta de revisões quantitativas na literatura sobre estes efeitos realizámos duas meta-análises (com 10 estudos mais recentes) para avaliarmos a sua magnitude e as dimensões das amostras (ver dados nas tabelas em anexo). A característica emocional ou familiaridade dos estímulos promovem distorções temporais de ordem moderada a elevada, com os intervalos de confiança do indicador da magnitude dos efeitos (i.e., d de cohen) a variarem entre d=0.25 e d=0.86, e d=0.26 e d=0.81 respectivamente. A dimensão média para os dois conjuntos de

[5] Neste artigo apenas referimos os julgamentos de duração realizados de forma prospectiva; ou seja, quando os participantes sabem a priori que a tarefa experimental envolve a estimação da duração de um determinado estímulo ou evento. Contudo uma outra abordagem (embora muito menos utilizada, ver Block & Zakay, 1997 para uma revisão), consiste em pedir estimativas sem que os participantes estejam conscientes à partida de que deverão estimar a duração de um intervalo de tempo. Alguns autores (e.g., Block, 1990; Brown, 1985) referem-se à abordagem prospectiva como a "*duração experienciada*" e à abordagem retrospectiva a "*duração rememorada*". Esta diferença metodológica acarreta consequências na experiência do tempo (para revisões ver Brown, 2010; Zakay & Block, 2004).

estudos rondou os 40-50 participantes, sendo que os efeitos são claramente detectados com amostras na ordem dos 20 participantes.

Variáveis independentes

O paradigma base apresenta duas variáveis independentes, a duração (i.e., variável temporal) e o promotor da ilusão (i.e., variável não-temporal).

Duração. A duração dos estímulos ou intervalos utilizados varia imensamente entre os estudos. Consultando as tabelas em anexo pode-se observar durações tão curtas como 10 ms (Stoyanova & Bohdanecky, 1988) ou mais longas como 2 min (Avni-Babad & Ritov 2003). Genericamente, dentro do campo da percepção de tempo, a gama de durações mais utilizada varia entre os 100 ms e os poucos segundos (Grondin, 2010). Contudo a escolha das durações não deverá ser arbitrária, dado ser esta uma variável que interage com as ilusões temporais produzidas por outras variáveis[6]. A utilização de múltiplas durações permite uma maior estabilidade da medida; sendo este factor quase exclusivamente manipulado intra-participantes.

Promotor da ilusão. Como princípio, a outra variável independente é o factor que prevê promover a ilusão temporal. Estes factores envolvem características não-temporais do estímulo que variam em dois ou mais níveis, por exemplo: emoção (emocional vs. neutro, e.g., Grommet et al., 2011); familiaridade (familiar vs. não-familiar, e.g., Witherspoon & Allan 1985); preenchimento (preenchido vs. vazio, e.g., Thomas & Weaver, 1975). O factor específico a ser utilizado será o adequado ao estudo em causa. Na *Tabela 1* estão listados vários promotores do efeito (associados a ilusões específicas), sendo que cada um destes tem as suas especificidades em termos de operacionalização. As manipulações dos níveis da variável não-temporal são feitas quase exclusivamente intra-participantes de forma prospectiva (ou seja, quando os participantes sabem a priori que a tarefa experimental envolve a estimação da duração de um determinado estímulo ou evento).

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[6] Alguns dados sugerem que diferentes mecanismos cognitivos e neurais encontram-se envolvidos no processamento de durações inferiores e superiores a 1 s (e.g., Fortin & Couture, 2002; Penney & Vaitilingam, 2008), e isso modera os efeitos (ver secção moderadores do efeito). A partir de 1 s existe uma tendência de segmentação cognitiva do tempo, por exemplo, através de contagens (e.g., Grondin, Meilleur-Wells, & Lachance, 1999), processo que tende a ser controlado pelos investigadores, evitando durações inferiores a 1 s ou por outros métodos (ver Rattat & Droit-Volet, 2012). Outro aspecto a ter em conta é o número de durações ou intervalos utilizados nos estudos. Este número, em julgamentos prospectivos, varia geralmente entre 3 e 5 durações distintas, mas depende da tarefa temporal utilizada (ver tabelas em anexo); por exemplo, em tarefas de discriminação são usualmente alvo de julgamento 6 a 8 durações distintas.

Medidas dependentes

Julgamentos de duração. Pode ser variável dependente qualquer medida temporal (ou indicador extraído da medida) que covarie com a duração objectiva do estímulo. São utilizados vários métodos (ou tarefas temporais) para quantificação subjectiva da duração (para revisão ver Allan, 1979; Grondin, 2008; Grondin, 2010), que aqui organizamos em 3 categorias:

1. *Métodos de dimensionamento.* Este conjunto de métodos consiste em aceder directamente a uma magnitude (que é estimada) em função da magnitude temporal (i.e., duração) do estímulo, feita com base em referenciais (habitualmente fornecidos ao participante). São utilizados em toda a gama de durações.

    a) *Estimação de magnitude (com base em unidade temporal aprendida).* O participante é familiarizado com um intervalo com uma certa uma duração que representa a unidade temporal; as estimativas das durações são feitas como múltiplos dessa unidade temporal (e.g., Avni-Babad & Ritov 2003).

    b) *Estimação verbal (com base em unidades temporais conhecidas).* O participante faz uma estimativa verbal da duração do estímulo usando unidades temporais como segundos ou minutos. Em durações mais curtas, por vezes são solicitadas respostas com casas decimais (e.g., Noulhiane et al., 2007).

    c) *Escala ('rating-scales').* Os julgamentos usam escalas (continuas) ancoradas em duração curta e longa, variando habitualmente de 3 (e.g., Masson & Caldwell, 1998) a 9 pontos (e.g., Reber et al., 2004). Por norma, existe uma fase de aprendizagem com durações objectivas (pelo menos a mais curta e mais longa da fase de teste)[7]. Estas escalas podem ser analógicas, ancoradas em unidades temporais de tempo objectivo, por exemplo, 0-10 segundos (Angrilli, Cherubini, Pavese, & Manfredini, 1997).

[7] É menos comum serem mostradas ao participante todas as durações intermédias, escalas categoriais (e.g., Witherspoon & Allan 1985) ou os referenciais da escala ficarem ao critério do participante (e.g., Masson & Caldwell, 1998), sendo neste caso estimativas totalmente relativas.

2. *Métodos de discriminação.* Agrupa as tarefas que recorrem à discriminação da duração de dois ou mais estímulos, por comparação directa (i.e., estímulos sucessivos) ou relativa a um ou mais referenciais (em memória). O participante faz um julgamento da duração do estímulo alvo e compara-o com outro(s). Nesta categoria de métodos (clássicos da psicofísica) é usual a utilização de séries temporais (6 a 8 durações) para computação de índices a partir das distribuições das respostas (ver secção redução de dados e análise estatística). Normalmente são utilizados apenas para durações breves (menos de 8 segundos).

    a) *Tarefa de comparação de estímulo constante*[8]:

        – *Uso de pares de estímulos.* Perante dois estímulos sucessivos o participante indica se o segundo estímulo é mais curto ou mais longo (do que o estímulo precedente). Nesta tarefa a duração do primeiro estímulo é sempre constante (i.e., standard) variando a do segundo (e.g., Ulrich, Nitschke, & Rammsayer, 2006).

        – *Uso de séries de estímulos.* Perante uma série de estímulos sucessivos com durações semelhantes o participante decide se um estímulo alvo (oddbal; ou posições específicas na série) é mais curto ou mais longo do que os restantes da série (Kanai & Watanabe, 2006; Pariyadath & Eagleman , 2007; Tse, Rivest, Intriligator & Cavanagh, 2004) .

    b) *Tarefa de comparação adaptativa*[9]. Similar ao uso de pares de estímulos. Nesta tarefa a duração standard vai sendo adaptada em função da resposta do participante (segundo determinados critérios psicofísicos, ver por exemplo Ivry & Hazeltine, 1995).

    c) *Tarefa de Bissecção.* Classificação da duração do estímulo alvo com base em duas durações extremas (curta e longa) aprendidas previamente, num procedimento de escolha forçada (ver Wearden, 1991; Droit-Volet, Brunot, & Niedenthal, 2004). Os estímulos alvo assumem durações extremas (aprendidas como longas e curtas) e outras intermédias a estas, tendo o participante de classificar as durações (destes estímulos) como "mais similar" à curta ou à longa.

[8] Na literatura esta tarefa é comumente designada por método de estímulo constante (MSC ou '*method of constant stimuli*').

[9] Na literatura esta tarefa é comumente designada por método de comparação adaptativa ('*adaptative method*').

d) *Generalização temporal.* Classificação da duração do estímulo alvo como maior ou menor que uma única duração standard, aprendida previamente (por apresentação de estímulos com essa duração) . (e.g., Gil & Droit-Volet, 2011; Wearden, 2008). A duração dos estímulos alvo toma valores inferiores, iguais e superiores à duração standard.

e) *Tarefa de detecção de sinal.* Classificação da duração do estímulo alvo com base em duas durações (uma curta e uma longa) aprendidas previamente. Os estímulos apenas assumem estas duas durações (e.g., Macar, Grondin, & Casini, 1994; Wittlesea, 1993). É um método menos utilizado na percepção de tempo.

3. *Métodos de geração.* Estes métodos exigem estimativas temporais contínuas. Ou seja, os participantes geram durações contínuas com base em referenciais fornecidos previamente. Tipicamente são utilizados em julgamentos de durações médias (segundos a minutos).

   a) *Produção.* O participante produz um intervalo de tempo (por norma aprendido anteriormente), marcando o início e o fim do intervalo (e.g., pressionando numa tecla 2 vezes) para uma duração julgada equivalente (e.g., Gil & Droit-Volet, 2011; Ono, Yamada, Chujo, & Kawahara, 2007).

   b) *Reprodução.* Neste caso, o participante reproduz a duração de um estímulo habitualmente apresentado imediatamente antes, através da mesma operação descrita no método da produção (e.g., Angrilli et al., 1997; Bar-Haim et al. 2010).

Têm sido reportadas correlações elevadas entre os resultados obtidos com diferentes métodos e tarefas (e.g., Grondin, 2008; Zakay, 1993)[10].

Procedimento

Apesar do procedimento variar em função dos métodos de julgamento de duração utilizados, em termos genéricos consiste em 2 ou 3 fases das descritas seguidamente.

[10] Note-se que a única dimensão partilhada pelos diferentes métodos e tarefas é a que subjaz o processo pelo qual o indivíduo acede à informação temporal. Diferentes processos cognitivos e neurais podem estar envolvidos nestes métodos como é sugerido por vários autores (e.g., Baudouin, Vanneste, Isingrini, & Pouthas, 2006; Brown, 1997), podendo mesmo induzirem diferentes resultados (e.g., Gil & Droit-Volet, 2011; Zakay & Block, 1997) (ver secção de moderadores).

Fase de aprendizagem. Nas tarefas de *estimação de magnitude* e de *generalização temporal*, estímulos (neutros) com apenas uma duração específica (e.g., 500 ms) são apresentados (para que os participantes com esta se familiarizem); no primeiro caso serve de unidade temporal para os julgamentos de duração e no segundo caso como duração *standard* para comparação com as durações dos estímulos alvo.

Nas tarefas de *bissecção* e com uso de *escalas*, são apresentados estímulos (neutros) com duas durações distintas, pretendendo-se que os participantes as discriminem; no caso da tarefa de *bissecção*, constituem as durações curta e longa a serem utilizadas como categorias de classificação das durações dos estímulos alvo, enquanto no caso das escalas servem como os valores extremos das mesmas. As restantes tarefas não necessitam desta fase, sendo cada tarefa descrita nas instruções.

Fase de treino. Na maior parte dos estudos é realizada uma fase de treino para que os participantes se familiarizem com a tarefa (que é descrita no ponto a seguir). No caso da utilização de durações muito breves (i.e., na ordem dos milissegundos) é essencial.

Fase de julgamento. Esta fase constitui o estudo propriamente dito. É pedido aos participantes (como instrução) que façam julgamentos de duração de um conjunto de estímulos (um a um) que são apresentados (habitualmente) no centro do ecrã do computador com base no método explicado previamente (ver secção de medidas dependentes). O período de tempo a estimar em cada ensaio coincide com o *onset* (i.e., momento de aparecimento) e *offset* (i.e., momento de desaparecimento) do estímulo. Mas outra forma de definir o intervalo de tempo a estimar é por meio de marcadores que indicam o seu início e o fim[11]. *Em cada ensaio os estímulos são apresentados isoladamente, com durações variáveis, seguindo-se o julgamento (subjectivo) da sua duração.*

Os métodos comparativos (de *estímulo constante* e *adaptativo*) apresentam uma excepção a este procedimento, visto que cada ensaio consiste na apresentação (não de um, mas) de dois estímulos sucessivos (separados por um intervalo variável). Neste caso é pedido que seja indicado se o segundo foi mais curto ou mais longo que o primeiro.

Nos métodos de discriminação (com excepção da *detecção de sinais*) as durações utilizadas são por norma mais de 5 com um número mínimo de 5 ensaios por cada duração e

[11] Estes marcadores são geralmente sonoros com uma duração normalmente inferior a 30 ms, e utilizados por exemplo em estudos sobre a ilusão de preenchimento (e.g., Thomas & Brown, 1974; Wearden et al., 2007).

nível da variável independente não-temporal, devido ao cálculo de proporções (ver secção de redução de dados e análise estatística).

Para estabilidade da medida, utilizando-se qualquer um dos métodos, é comum um número elevado de ensaios por cada nível das variáveis independentes, o que acarreta, por exemplo, nos métodos de discriminação a realização de muitos ensaios (ver tabelas em anexo). É por isso comum a divisão desta fase em vários blocos de ensaios com pausa (i.e., alguns minutos) e retoma com apresentação das instruções novamente, para evitar cansaço e aborrecimento. Os ensaios são apresentados aleatoriamente.

Redução de dados e análise estatística

Em função do número de ensaios por condição experimental e do método de julgamento de duração, são calculados diferentes índices nas análises estatísticas para teste das ilusões temporais.

Métodos de dimensionamento (i.e., estimação de magnitude, estimação verbal e escalas) e métodos de geração (i.e., produção e reprodução): os valores são agregados em médias gerais. É frequente o cálculo do rácio da duração subjectiva pela duração objectiva ($D=D_{subjectiva}/D_{objectiva}$) separadamente para cada uma das condições experimentais (e.g., Brown, 1985; Hornstein & Rotter, 1969; Tobin, Bisson, & Grondin, 2010). A análise deste rácio permite tornar comparáveis os vários níveis da variável não-temporal (em função das diferentes durações) e principalmente dos diferentes métodos de julgamento que possam eventualmente ter sido utilizados no estudo. É comum também calcular este rácio ponderado pela duração objectiva ($D=(D_{subjectiva}-D_{objectiva})/D_{objectiva}$) (e.g., Angrilli et al., 1997; Noulhiane et al. 2007; Treisman, 1963). O efeito associa-se ao contraste de pelo menos dois níveis da variável não-temporal e devido à manipulação de outra variável independente (i.e., a duração, variável temporal), este contraste é testado numa análise de variância (ANOVA) de medidas repetidas de dois factores. Espera-se um efeito principal significativo da variável não-temporal nos julgamentos de duração (moderada ou não pela variável temporal).

Medidas de discriminação (i.e., método de estímulo constante, método adaptativo, bissecção, generalização temporal e detecção de sinal): é regra a computação das proporções do total de respostas (curtas ou longas) para cada nível das variáveis independentes. Com excepção do método de detecção de sinal, devido à utilização de uma série de durações (6-8) permite desenhar uma função psicofísica para cada nível da variável não-temporal; que

consiste na relação da proporção de respostas (normalmente longas) em função da duração objectiva dos estímulos – 0% e 100% representam perfeita discriminação. Isto permite, através de diferentes métodos, calcular o ponto de igualdade subjectiva (ou ponto de bissecção) que traduz a incapacidade para discriminar, ou 50% de probabilidade de dar uma resposta longa. Um método de cálculo utilizado é através do ajustamento de parâmetros a modelos logísticos (e.g., Killeen, Fetterman, & Bizo, 1997). Quanto menor o ponto bissecção maior a estimativa temporal. Utilizando proporções ou pontos de bissecção recorre-se igualmente a análise de variância (ANOVA) de medidas repetidas para testar o efeito. No caso da detecção de sinais recorre-se ao cálculo do índice de discriminação d', que é computado pelas proporções normalizadas de acertos (responder "longo" a durações objectivas longas) e de falsos alarmes (responder longo a durações objectivas curtas) (e.g., Macar, Grondin, & Casini, 1994).

Variações do paradigma

Os efeitos de ilusão temporal têm sido encontrados com diferentes tipos de manipulações experimentais ligeiramente distintas daquela indicada no paradigma base. No paradigma base fazem-se variar características (não-temporais) dos estímulos a serem alvo de estimação temporal (e.g., tamanho; natureza emocional do estímulo). Noutro tipo de manipulações os estímulos são dinâmicos (i.e., apresentam componentes temporais) (e.g., movimento, frequência temporal). Destacamos igualmente manipulações das condições (ou contexto) de apresentação (e.g., ordem temporal, *oddball*); processamento explícito simultâneo de informação temporal (i.e., a duração a estimar) e informação não-temporal (e.g., sobrecarga cognitiva); e manipulações dos estados do indivíduo, previamente à tarefa temporal (e.g., estado de espirito ou *mood*). A Tabela 1 resume algumas destas ilusões temporais.

Tabela 1. Ilusões temporais.

Variável Promotora	Ilusão	Direção	Referências
Familiaridade	Estímulos mais familiares aparentam durar mais tempo	↑	Kleider & Goldinger (2004); Masson & Caldwell (1998); Witherspoon & Allan (1985)
Emoção	Estímulos emocionais aparentam durar mais	↑	Droit-Volet et al. (2004); Mella et al. (2010); Tipples (2008)

	tempo que estímulos neutros		
Preenchimento	Intervalos preenchidos aparentam durar mais tempo que intervalos vazios	↑	Craig (1973); Thomas & Brown (1974); Wearden et al. (2007)
Luminosidade (intensidade)	Objectos com mais brilho aparentam durar mais tempo	↑	Goldstone, Lhamon, & Sechzer (1978); Matthews, Stewart, & Wearden, (2009); Xuan, Zhang, He, & Chen (2007)
Tamanho	Objectos maiores aparentam durar mais tempo	↑	Ono & Kawahara (2007); Robertson & Gomez (1980); Xuan et al. (2007)
Contraste	Estímulos mais fáceis de percepcionar são percebidos como mais longos	↑	Bruno & Johnston (2010); Stoyanova, Yakimoff & Mitrani (1987); Terao et al. (2008)
Frequência Espacial / Número	Estímulos compostos por vários elementos aparentam ter durações maiores	↑	Dormal, Seron, & Pesenti (2006); Javadi & Aichelburg (2012); Xuan et al., (2007)
Movimento	Objectos em movimento aparentam durar mais tempo que objectos estacionários	↑	Brown (1995); Kanai, Paffen, Hogendoorn & Verstraten (2006); Kaneko & Murakami (2009)
Frequência temporal	Maior frequência temporal de estímulos é percebida com uma duração mais longa	↑	Burle & Bonnet (1997); Burle & Casini (2001); Ortega & López (2008)
Processamento activo	Quanto maior o envolvimento no processamento da informação não-temporal menor a duração percebida	↓	Coull et al., (2004); McClain (1983); Predebon (1996)
Sobrecarga cognitiva	Manter informação em memória durante o intervalo diminui a sua duração subjectiva	↓	Fortin & Breton (1995); Fortin, Rousseau, Bourque, & Kirouac (1993)
Destaque / Novidade	Maior destaque (oddball) de um estímulo numa série de estímu-los maior a duração percebida	↓	Pariyadath & Eagleman (2007); Schindel, Rowlands, & Arnold (2011); Tse et al. (2004)
Erro de ordem temporal	Utilizando o método compa-rativo de estímulo constante o segundo intervalo relativamente ao primeiro aparenta ser mais curto quanto maior a duração	↓	Hellström (1978); Hellström & Rammsayer (2004); Woodrow (1935)
Estado de espírito	Quanto mais negativo (ou	↑	Droit-Volet, Fayolle & Gil (2011);

(*Mood*)	positivo) for o estado de espírito induzido no participante maior a duração percebida		Kellaris & Mantel (1994)
Arousal (fisiológico)	Quanto maior a activação fisiológica no participante maior a duração percebida	↑	Hancock (1993); Rammsayer (1989); Treisman, Faulkner, Naish, & Brogan (1990)

Variáveis Moderadoras

A literatura que foca as ilusões temporais sugere-nos um conjunto de variáveis que se constituem como moderadores dos efeitos. Na Tabela 2 encontram-se várias destas variáveis, indicando-se algumas das suas evidências empíricas.

Tabela 2. Moderadores das ilusões temporais

Moderador	Evidências
Manipulação inter e entre-participantes	O efeito diminui ou desaparece quando a manipulação da variável não temporal é feita entre-participantes. Esta moderação já foi detectada nos efeitos da emoção (Lee, Seelam, & O'Brien, 2011), preenchimento (Droit-Volet, 2008) e tamanho (Robertson & Gomez, 1980).
Método de julgamento	Estudos que testaram ilusões temporais utilizando vários métodos simultaneamente, demonstraram que os efeitos não são homogéneos (e.g., Bisson, Tobin, & Grondin, 2009; Gil & Droit-Volet, 2011; Wearden, 2008).
Duração	Observa-se frequentemente um efeito não homogéneo ao longo da série de durações utilizadas dentro do mesmo estudo (e.g., Angrilli et al., 1997; Noulhiane et al. 2007; Smith, McIver, Nella, & Crease, 2011).
Tipo de manipulação	Apesar de muitas ilusões temporais serem robustas, existem algumas especificidades. A ilusão de dilatação da duração promovida pela familiaridade depende do tipo de operacionalização deste factor; por exemplo, os efeitos são invertidos quando se utiliza a primação de repetição (Masson & Caldwell, 1998; Ono, Kawahara, & Matsuda, 2004).
Tipo de estímulos	Por exemplo, tem-se verificado que nem todo o tipo de estímulos emocionais promove o mesmo tipo de ilusão (i.e., sobrestimativa); no caso de faces expressando vergonha o efeito é invertido (Gil & Droit-Volet, 2011); faces de raiva de pessoas a olhar para o lado diminuem o efeito (Doi & Shinohara, 2009).
Ordem	Os intervalos são consistentemente percebidos como mais longos quando apresentados numa segunda fase da experiência do que na primeira (Schab & Crowder, 1988) tendo implicações, por exemplo, na manipulação de familiaridade (Block et al., 2010).
Tipo de marcadores do	O tipo de estímulos breves que servem de marcadores (de início e

intervalo	término) de um intervalo tem impacto nos julgamentos dessa duração (Grondin, 1993).
Modalidade sensorial	Os efeitos aparentam ser de maior magnitude para estímulos auditivos do que para visuais (e.g., Penney, Gibbon, & Meck, 2000; Wassenhove et al., 2008;).
Idade	Para algumas variáveis têm-se verificado moderações do efeito pela idade dos participantes. Por exemplo, os efeitos de preenchimento têm maior magnitude em crianças (Droit-Volet, 2008), mas não se encontram diferenças para os efeitos da emoção (Gil et al., 2007).
Características individuais	Têm sido identificadas várias características dos indivíduos que moderam as ilusões temporais induzidas por algumas variáveis. Temos os exemplos, da ansiedade (Tipples, 2008), capacidade da memória de trabalho (Woehrle & Magliano, 2012), grupo étnico (Mondillon et al., 2007), especialidade (Rhodes & McCabe, 2009), esquizofrenia (Carrol et al., 2009).
Julgamentos imediatos e com delay	O retardar forçado da resposta após a apresentação dos estímulos tem mostrado interferir com a magnitude de algumas manipulações, habitualmente anulando as diferenças (e.g., Pedri & Hesketh, 1993; Vitulli & Shepard, 1996; Zakay & Fallach, 1984).
Julgamentos temporais e não-temporais simultâneos / Processamento activo	Quando os participantes atendem explicitamente às características dos estímulos inerentes ao factor não-temporal (realizando simultaneamente julgamentos não-temporais e temporais) o efeito tende a ser moderado por este factor (e.g., intensidade emocional, Mella, Conty, & Pouthas, 2010; cor, Coul, Vidal, Nazarian, & Macar, 2004).

Variáveis Tipicamente Associadas ao Paradigma

Cada variável estudada como promotor de uma ilusão temporal, é por vezes acompanhada de uma medida posterior com o objectivo de se verificar a eficácia da manipulação realizada. Por exemplo, no estudo de Witherspoon e Allan (1985) em cada ensaio foram feitos julgamentos de duração e de reconhecimento dos estímulos, estes para averiguar se os mesmo tinham sido apresentados numa fase prévia da experiencia para manipulação da familiaridade. No estudo de Angrilli et al. (1997) foram solicitados julgamentos de intensidade e valência dos estímulos emocionais utilizados para manipular estas variáveis no teste aos seus efeitos em julgamentos de duração.

Alguns Exemplos do Uso do Paradigma

Witherspoon e Allan (1985)

Na primeira experiência deste trabalho, os participantes numa primeira fase (de familiarização) leram, em voz alta, 80 palavras apresentadas ao ritmo de uma por segundo.

Depois de uma fase de treino, na fase experimental do estudo, 80 palavras (40 lidas anteriormente e 40 novas) foram apresentadas com as durações de 30 ms ou 50 ms. A seguir a cada apresentação, os participantes tinham de identificar a palavra (em voz alta) e depois estimar a duração (numa escala de 1, curto, a 4, longo). Os dados demonstraram que apenas uma única apresentação de uma palavra influencia a sua percepção posterior, não só melhorando a sua identificação perceptiva mas também promovendo uma sobrestimativa temporal (i.e., durações subjectivas mais longas para estímulos mais familiares). A segunda experiência foi equivalente à primeira onde neste caso só se pediram julgamentos de duração, mostrando que a identificação perceptiva não é necessária para promover uma sobrestimativa temporal das palavras mais familiares. Os autores concluem que os julgamentos de duração podem consistir numa medida dependente de memória razoável, explicando os resultados com base da hipótese de falsa atribuição à fluência perceptiva (ver a secção seguinte).

Droit-Volet (2008)

Nestes estudos, foram realizadas duas experiências sobre a ilusão de preenchimento em crianças (5 e 8 anos) e adultos, usando o método de bissecção temporal (ver secção Medidas Dependentes) com duas séries de durações (1, 1.5, 2, 2.5, 3, 3.5, 4 s; 2, 3, 4, 5, 6, 7, 8 s). Na primeira experiência, os participantes tiveram que categorizar a duração como curta ou longa de estímulos sonoros contínuos (duração ‘preenchida’) com uma frequência de 500 Hz e de intervalos de equivalentes durações assinalados por marcadores sonoros de 20 ms (duração ‘vazia’). Na segunda experiência o tipo de estímulo (preenchido ou vazio) foi manipulado entre-participantes. As análises dos pontos de bissecção (ver secção de Redução de Dados) e outros índices revelaram um efeito marcado do preenchimento apenas na primeira experiência (manipulação intra-participantes), com as durações ‘preenchidas’ serem julgadas como mais longas que as durações ‘vazias’ em todos ou grupos etários. Os autores explicam a ilusão de preenchimento com base nos modelos de relógio interno (ver a secção seguinte), em que o som contínuo (duração preenchida) promoveria um aumento do *arousal* e consequentemente na velocidade do relógio interno. A ausência de efeito na manipulação entre-participantes é explicada como o resultado das estimativas não terem como base o mesmo relógio interno, apresentando velocidades diferentes para diferentes participantes (i.e., basicamente um efeito de contraste).

Yamada e Kawabe (2011)

Este estudo procurou investigar se estímulos emocionais ‘invisíveis’ (não detectáveis conscientemente) teriam impacto na percepção de tempo. Utilizando um *flash* contínuo de

supressão, que consiste num tipo de máscara dinâmica inter-ocular, imagens emocionais supra-liminares (do conjunto normativo IAPS) foram mascaradas ou não-mascaradas dependendo se a posição da retina dos *flashs* contínuos num olho era consistente com a das imagens no outro olho. O conjunto da máscara (quadrados coloridos) e da imagem emocional (positiva, neutra ou negativa) foram apresentados com a duração de 2700 ms sendo realizado o método de reprodução para estimar o tempo (ver secção de Medidas Dependentes) a seguir a cada um dos estímulos. Como resultado, a duração dos estímulos emocionais negativos foi percebida como mais longa relativamente aos estímulos positivos e neutros, independentemente se os estímulos emocionais eram visíveis ou não. Os autores sugerem que as emoções negativas (pelo menos) aceleram o relógio interno (ver secção seguinte) de forma inconsciente alterando a percepção de tempo.

As Explicações Teóricas

Modelos de Relógio Interno

Não estando os humanos equipados com nenhum tipo de receptor sensorial que permita captar a informação temporal (e.g., Coull, Cheng & Meck, 2011) estes modelos assumem a existência de um mecanismo interno para medir o tempo, operando como se de um relógio (cronómetro) se tratasse[12]. Este relógio interno é postulado (e.g., Creelman, 1962; Gibbon, Church & Meck, 1984; Treisman, 1963; Zakay & Block, 1996) ser um sistema central que regista a duração subjectiva dos eventos com base na acumulação de unidades temporais [13] ao longo do tempo, assinalados por algum tipo de marcador (i.e., início e término do intervalo. Os modelos mais prevalecentes (SET: Gibbon, Church & Meck, 1984; AGM: Zakay & Block, 1996), definem este relógio em três componentes centrais[14]: (1) um processador temporal ('*pacemaker*'); (2) um interruptor[15] ('*switch*'); (3) um acumulador. O processador temporal opera como um gerador que emite pulsos continuamente a uma determinada frequência, enviando-os para o acumulador através do interruptor. No início do estímulo a ser cronometrado, o interruptor (com uma latência variável) é accionado

[12] Existem vários exemplos de modelos que não se baseiam no conceito de relógio mas noutros processos como aqueles baseados em representações neurais de estados de processamento distintos (e.g., Karmarkar & Buonomano, 2007) ou no decaimento mnésico (e.g., Staddon & Higa, 1999).

[13] Unidades hipotéticas que consistem em unidades mínimas informacionais de tempo, sejam conceptualizadas como meramente cognitivas ou de cariz biológico (ou neural).

[14] Os modelos mais recentes dos quais se incluem o SET e o AGM compreendem 3 fases de processamento das quais a do relógio interno é uma delas (a primeira) e a única aqui discutida. Vários efeitos nos julgamentos de duração podem resultar em função de interferências nestas fases de processamento da informação temporal.

[15] Em alguns modelos como o AGM (Attentional Gate Model) este interruptor integra ainda outro componente, um portão ('gate'), que controla o foco e recursos atencionais dedicados ao processamento explícito do tempo. Para uma discussão sobre estas diferenças ver Lejeune (1998) e Zakay (2000).

(fechando-se), permitindo que os pulsos sejam transferidos para o acumulador (memória de trabalho) durante o intervalo, até ao seu término, quando o interruptor volta a abrir. Deste modo, o número de pulsos registados no acumulador constituirá a representação da duração percebida: quanto maior o número de pulsos, maior a duração percebida.

Estes modelos de relógio interno permitem fazer predições sobre as distorções e ilusões temporais que surgem como resultado de interferências em algum dos vários componentes do relógio. Duas fontes principais de distorção temporal (i.e., subestimativas ou sobrestimativas) têm sido amplamente estudadas e sugeridas na literatura: (1) processos relacionados com a atenção e recursos atencionais; e (2) processos relacionados com o *arousal* ou activação (cognitiva ou fisiológica).

1. *Atenção*. É proposto a atenção interferir ao nível do interruptor[16] (e.g., Lejeune, 1998; Zakay & Block, 1996). O interruptor deverá abrir apenas quando o evento termina, mas os desvios atencionais (i.e., repartição de recursos entre o processamento da informação temporal e não-temporal[17]), poderão fazê-lo abrir e fechá-lo (várias vezes) ao longo do intervalo, reduzindo o número de pulsos a entrarem no acumulador (na memória de trabalho), sendo a duração estimada como mais curta[18]. Exemplo de ilusão temporal: tem sido sugerido que a sobrestimativa temporal promovida pela familiaridade deve-se à maior facilidade de processamento da informação não temporal dos estímulos que permite maior foco atencional na informação temporal (e.g., Avni-Babad & Ritov 2003; Rhodes & McCabe 2009; Stoyanova & Bohdanecky, 1988).

2. *Arousal*. O *arousal* é pressuposto interferir com o *pacemaker*, (para revisões ver Droit-Volet & Meck, 2007; Wearden, 2005). Em função do aumento do *arousal*[19], o *pacemaker* aumenta a sua frequência de emissão de pulsos, implicando um maior número de pulsos acumulados (na memória de trabalho) durante o intervalo, sendo a sua duração, consequentemente, julgada como mais longa. Exemplo de ilusão

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[16] Ou portão atencional como descrito no modelo AGM, em que as unidades temporais geradas são registadas apenas quando a atenção é dirigida para o tempo (Zakay and Block, 1996) levando à abertura do portão, alimentando o acumulador ou contador.

[17] A proposta da atenção interferir com este mecanismo cronométrico foi considerada já nos primeiros modelos de relógio interno (e.g., Hicks, Miller, & Kinsbourne, 1976; Thomas & Brown, 1974; Treisman, 1962), que advogavam que a repartição de recursos atencionais (ou alternância do foco atencional) entre a informação temporal e não-temporal diminui a duração subjectiva. Esta repartição (de recursos limitados) reduz a capacidade para processar a informação temporal, foco atencional central no paradigma prospectivo (Kahneman, 1973; para uma revisão ver Brown, 2008).

[18] Este mecanismo parece ser muito sensível a manipulações atencionais, como foi demonstrado inúmeras vezes na literatura (para uma meta-análise ver Block, Hancock & Zakay, 2010).

[19] Vários tipos de manipulação de *arousal* têm sustentado robustamente esta hipótese: (a) a temperatura corporal (para uma revisão ver Wearden & Penton-voak, 1995); (b) estímulos repetitivos de elevada frequência (e.g., Droit-Volet & Wearden, 2002; Penton-Voak, Edwards, Percival, & Wearden, 1996; Treisman & Brogan, 1992); e (c) substâncias farmocológicas (para uma revisão ver Rammsayer, 2008).

temporal: parece ser a dimensão de activação (*arousal*) associada à experiência emocional (sempre mais elevada do que aquela associada ao processamento de estímulos neutros), que promove a duração de estímulos emocionais ser estimada como mais longa (para uma revisão ver Droit-Volet & Meck, 2007).

Eficiência de Codificação Neural

Estes modelos postulam a codificação da passagem do tempo como sendo feita através da modificação ao longo do tempo da actividade das próprias redes neuronais que genericamente processam os estímulos, particularmente nos córtices sensoriais e córtex parietal (Buonomano & Mauk, 1994; Buonomano & Merzenich, 1*995;* Mauk & Buonomano, 2004; Karmarkar & *Buonom*ano, 2007; Ivry & Schlerf 2008). Designados de modelos de "*dependência-de-estado*" de*vido* ao facto de ancorar nas mudanças de estado das redes neuronais durante a apresentação de um estímulo; sendo essa sucessão de padrões únicos de activação uma forma de codificar o próprio tempo. Eagleman e colaboradores (Eagleman & Pariyadath, 2009; Eagleman, 2008; Pariyadath & Eagleman, 2007; Sadeghi, Pariyadath, Apte, Eagleman & Cook, 2011) adicionaram poder explicativo (de várias ilusões temporais) a estes modelos sugerindo que a duração subjectiva também depende, da eficiência da codificação neural[20]. Por outras palavras, quanto maior for a amplitude da resposta neural (ou energia despendida) promovida pelo estímulo, durações mais longas serão percebidas. Corroborando esta ideia Sadeghi e colaboradores (2011) demonstram não só que a amplitude da resposta neural se correlaciona com a distorção temporal, mas também que a representação neural fica durante mais tempo activa em resposta a um estímulo mais intenso. Este modelo fornece uma hipótese explicativa de várias das ilusões temporais, como a luminosidade ou intensidade de um estímulo associadas a sobrestimativas temporais.

Hipóteses Genéricas de Enviesamento

Os enviesamentos temporais têm sido explicados com base em características gerais do processamento cognitivo encarando as estimativas temporais como qualquer outro tipo de

[20] Estes autores, partindo dos estudos que mostram que estímulos repetidos aparentam durar menos que estímulos novos apresentados em série (e.g., Tse et al., 2004; Pariyadath & Eagleman, 2007; Schindel, Rowlands, & Arnold, 2011; Pariyadath & Eagleman, 2008; Matthews, 2011) sugeriram um paralelismo com o fenómeno da supressão neural por repetição (e.g., Wark et al., 2007; Ranganath & Rainer, 2003). Este fenómeno consiste na diminuição rápida da amplitude da resposta neural em regiões corticais (sensoriais e associativas) após a apresentação repetida de um estímulo.

julgamento (não fornecendo modelos de explicação específicas do julgamento temporal[21]). Estas abordagens referem o julgamento temporal como sendo ancorado numa característica de processamento, que na situação de ilusão é afectada por outras variáveis para além do tempo.

1. *Julgamento ancorado na fluência de processamento*. Esta abordagem sugere que o ser humano ancora alguns dos seus julgamentos temporais num índice de rapidez, facilidade de processamento. Qualquer outra variável que interfira com essa facilidade de processamento do estímulo (i.e., fluência) é falsamente atribuída à dimensão de julgamento[22] Jacoby e Dallas (1981) foram os primeiros a sugerir que os participantes podem atribuir incorrectamente a fluência perceptiva a durações de apresentação mais longas: quanto mais fluente for o processamento (perceptivo) de um estímulo mais longa a duração percebida. Por exemplo, esta explicação parece sustentar as ilusões temporais relacionados com familiaridade que é associada a maior fluência (e.g., Kleider & Goldinger 2004; Masson & Caldwell, 1998; Whittlesea, 1993; Witherspoon & Allan, 1985).

2. *Existência de uma representação unitária de magnitude.* A ATOM ('Theory of Magnitude'; Walsh,2003) sugere-nos que a sobreposição processual e de representação de magnitude entre as dimensões, como por exemplo, de tempo, espaço e tamanho, poderá estar na base de algumas das ilusões temporais (Goldstone et al., 1978; Xuan et al., 2007). Esta hipótese consiste na correspondência das magnitudes em ambas as dimensões (temporal e não-temporal) mais = mais (longo) e menos = menos (curto). Assim, são considerados mais longos estímulos visuais mais luminosos (e.g., Goldstone et al., 1978; Matthews et al., 2011; Xuan et al., 2007) ou de maior tamanho (e.g., Gomez & Robertson, 1979; Robertson & Gomez, 1980; Xuan et al., 2007).

Sumário

Definimos aqui um paradigma que é genericamente associado ao estudo das ilusões temporais. Este é definido por se pedir aos participantes que façam julgamentos de duração de

[21] Note-se que nos estudos sobre ilusões temporais, apesar de se observarem interacções entre a variável temporal (duração) e as variáveis não-temporais (e.g., Angrilli et al., 1997; Noulhiane et al. 2007; Smith et al., 2011), os efeitos da variável não-temporal são sempre de menor magnitude que os efeitos da duração. É importante referir aqui que não se encontram inversões dos efeitos entre as variáveis não-temporais e a variável temporal, sendo que estas explicações apenas têm poder explicativo para os enviesamentos nos julgamentos. Não substituem portanto os modelos de processamento temporal que explicam as regularidades das estimativas temporais

[22] São abundantes as evidências do impacto da fluência em vários tipos de julgamento, como de preferência afectiva (e.g., Whittlesea, 1993), de verdade (e.g., Begg, Anas, & Farinacci, 1992); de tamanho (e.g., Reber, Zimmermann, & Wurtz, 2004) ou de contraste (e.g., Reber et al., 2004).

diferentes estímulos que variam simultaneamente na sua duração e numa dimensão (não-temporal) específica (e.g., familiaridade, natureza emocional, contraste, preenchimento). Deixamos claras as várias dimensões cujo impacto na percepção de tempo (i.e., sobrestimativa ou subestimativa) tem sido sistematicamente observado na literatura, e por isso ganho o epíteto de ilusão temporal.

O paradigma apesar de ser unitário pode ser operacionalizado de muitas e diferentes formas, através da selecção de um de vários métodos de mensuração das estimativas temporais. Identificamos aqui três categorias de julgamentos temporais associando-se a cada uma diferente tipo de tarefa (*métodos de dimensionamento*: estimação de magnitude, estimação verbal, e escalas; *métodos de discriminação*: comparação de estímulo constante, comparação adaptativa, bissecção, e detecção de sinal; e *métodos de geração*: produção, e reprodução temporal), tendo estes, diferentes implicações para a análise dos dados subsequentes.

Desde as primeiras demonstrações de ilusões temporais (e.g., Hall & Jastrow, 1886) vários autores procuraram compreender os mecanismos que estão na base destes fenómenos, assim como identificar os factores que os modificam ou anulam, definindo um conjunto de variáveis moderadoras aqui identificadas e que são utilizadas como argumentos em favor de uma ou outra das diferentes explicações teóricas que têm sido apresentadas (i.e., modelos de relógio interno, eficiência neural, fluência de processamento, representação unitária de magnitude).

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Anexos

Tabela 1. Meta-análise dos efeitos da emoção na percepção de tempo

Estudo	n	Estímulos	Tarefa	Durações	Nº Durações	Ensaios	d	LL	UL
Droit-Volet et al. 2004	37	Faces	Bissecção	.4-1.6	7	252	.52	.19	.86
Effron et al. 2006	40	Faces	Bissecção	.4-1.6	7	189	.98	.46	1.50
Gil et al. 2007	83	Faces	Bissecção	.4-2.4	14	112	.86	.61	1.11
Noulhiane et al. 2007 [1]	24	Sons	Reprodução	2-6	3	108	1.55	.96	2.13
Tipples 2008	42	Faces	Bissecção	.4-1.6	7	112	.25	-.06	.55
Gil et al. 2009	63	Imagens	Bissecção	.4-1.6	7	189	-.47	-.73	-.21
Bar-Haim et al. 2010	58	Faces	Reprodução	2-8	3	144	.29	.03	.55
Mella et al. 2010	19	Sons	Comparação	2	1	72	.81	.31	1.31
Fernandes & Garcia-Marques 2010	108	Faces	Bissecção	.4-1.6	7	98	.33	.03	.64
Grommet et al. 2011	40	Imagens	Bissecção	.4-2.4	14	168	.76	.41	1.10
Médias	51				7	144			
Meta-análise	514					*Random effects*	$.55^{***}$	.25	.86

$^{**}p<.001$, $^{***}p<.0001$

Tabela 2. Meta-análise dos efeitos da familiaridade na percepção de tempo

Estudo	n	Estímulos	Tarefa	Durações	Nº Durações	Ensaios	d	LL	UL
Witherspoon & Allan 1985 [1]	21	Palavras	Escala	.03-.05	2	80	.71	.25	1.18
Reingold & Merikle 1988 [1]	20	Palavras	Comparação	.05	1	432	.53	.07	.98
Stoyanova & Bohdanecky 1988	6	Faces	Magnitude	.01-.07	5	900	1.20	.23	2.17
Whittlesea 1993 [6]	37	Palavras	Comparação	.07-.13	2	120	-.09	-.44	.26
Masson & Caldwell 1998 [2]	30	Palavras	Escala	.03-.06	2	150	1.00	.57	1.43
Avni-Babad & Ritov 2003 [3]	39	Palavras	Magnitude	120	1	1	.88	.23	1.52
Reber et al. 2004 [1]	16	Palavras	Escala	.03-.08	4	192	1.03	.45	1.62
Kleider & Goldinger 2004 [7]	59	Faces	Escala	1-2	3	36	.37	.10	.63
Ono et al. 2007	14	Padrões	Produção	2	1	180	-.30	-.81	.21
Rhodes & McCabe 2009	117	Palavras	Escala	.05-.07	2	120	.56	.19	.93
Médias	36				2	221			
Meta-análise	359					*Random effects*	$.53^{***}$	.26	.81

$^{**}p<.001$, $^{***}p<.0001$