**Published as: Nuyens, P., Lopez-Fernandez, O., Kuss, D. & Griffiths, M.D. (2021). The arousing and attentional effects of facial expressions on time perception: A systematic review. *BPS Cognitive Psychology Bulletin,* 6, 25-33.**

Filip M. Nuyens[1*] Daria J. Kuss[1] Mark D. Griffiths[1] & Olatz Lopez-Fernandez[12]

[1]Nottingham Trent University, Psychology Department, Nottingham, United Kingdom

[2]Monash University, Turning Point, Richmond, Australia

Address: International Gaming Research Unit, Psychology Department, Nottingham Trent University, 50 Shakespeare Street, Nottingham, NG1 4FQ

Email: filip.nuyens2016@my.ntu.ac.uk

**Abstract**

Although time perception has mainly been explored through the prospective paradigm, it appears that emotional stimuli lead to an overestimation of time either through an arousing or an attentional effect. Amongst the emotional stimuli, emotional expressions are of interest due to their social importance. The purpose of this paper was to systematically review research carried out into emotional expression interference on time perception. A systematic literature review of 13 peer-reviewed papers with an empirical design that tested healthy participants was conducted on studies exploring both time perception and emotional expression. Furthermore, the papers were only included if they were written in English language and dated from at least the year 1964 (i.e., following Treisman's model of time perception in 1963). Findings showed a congruent overestimation when participants were exposed to emotional faces, especially when they expressed anger. This interaction was mediated by the dynamism of the stimuli used (i.e., there was a stronger effect if the expressions were animated), the model gaze and direction (i.e., nullified effect when the face was directed away from the participant), the embodiment effect (i.e., nullified effect when participants could not mimic the expression), and participant age (i.e., stronger effect of positive expressions amongst elderly participants). In conclusion, it emerged that two underlying mechanisms explain the overestimation observed when confronted with emotional expressions – attention and arousal. Although these two mechanisms appear to impair time perception independently, the studies on the stimuli dynamism indicated a potential conjoint effect of these mechanisms.

## Introduction

Time perception is the ability to estimate the duration of an event or to compare an event duration with another event duration (i.e., deciding if one event duration is longer or shorter than another). Time perception can be separated into retrospective and prospective time perception (Levin & Zakay, 1989). In prospective time perception (PTP), individuals are aware that they will have to estimate the duration of an event. The investigator tells the participant the aim of the experiment beforehand, so that the participant can focus on time itself (Block et al., 2010). In retrospective time perception (RTP), individuals are unaware that they will have to estimate the duration of the task until the very end of the experimental trial(s). RTP is therefore more ecologically valid because in real life, individuals rarely use PTP (Block, 2003).

One of the most commonly used models accounting for the RTP is the Contextual Change Model (CCM; Block & Reed, 1978). According to this model, a retrospective time estimation is based on experienced contextual changes within a period. If more events are observed, the perceived duration will be longer. However, PTP is more frequently described by the Scalar Expectancy Theory model (SET; Gibbon et al., 1984). This model includes four parts: a clock (i.e., with a pacemaker emitting pulses into an accumulator via a switch), working memory, a reference memory, and a comparator. The stocked pulses are compared to a remembered amount of pulses in the reference memory (i.e., a comparator part), and if the two values match, the values will be judged as equal. This value in the accumulator is also transferred to working memory in case it needs deeper processing. Compared to the cognitive models of RTP, the SET model does not entirely account for the observed effects of attention on time perception. Indeed, while the switch can operate an all-or-nothing effect, it does not account for gradual change. In order to overcome this issue, the model was modified by Zakay and Block (1995) adding a gate between the pacemaker and the accumulator, resulting in the Attentional Gate Model (AGM). The gate is a cognitive mechanism which opens according to attention to time (i.e., the more attention is allocated, the wider the door is opened). Therefore, more pulses reach the accumulator and the perceived duration is lengthened. Finally, the model also includes a switch, allowing the opening or closing of the door.

The effect of emotion on time perception varies depending on the paradigm of the timing (i.e., RTP or PTP). In RTP, the most plausible effect is a lengthening of time estimation when confronted with emotional stimuli. This is because emotional stimuli are remembered more easily and vividly (e.g., Xie & Zhang, 2017; Zlomuzica et al., 2016), and hence the estimation produced by the individual should be longer. An overestimation of time duration should also be observed using the PTP model; however, the situation is more complex. The overestimation could be the result of to two different processes, either an arousing process (i.e., increase of the pulse rate) or an attentional process (i.e., closing of the attentional gate).

Researchers have explored the impact of emotional expressions on time perception. Although an individual can be confronted with disgusting, sad, or scary stimuli (e.g., landscapes, object, and situations), individuals are more often confronted with emotional expressions in their everyday life. This has caught researchers' attention in the field of time perception, but there has never been a systematic review on this topic. Consequently, the aim of the present paper was to systematically review the effect of emotional expressions on time perception, as well as the variables influencing this interaction.

**Method**

A systematic literature review was conducted using four databases in December 2018: *Google Scholar, Science Direct, PubMed,* and *PsycINFO.* All of the searches included a common set of search words (i.e., time perception and timing), and other words to specify the particular field studied (e.g., emotion, and expression). Studies were included if they: (i) dated from the year 1964 (i.e., following Treisman's model of time perception in 1963), (ii) included an empirical design, (iii) included healthy participants, and (iv) were peer-reviewed and published in the English language.

The search undertaken on *Science Direct, PubMed,* and *PsycINFO* included the same type of research terms. Using the words, time perception and timing, with the specific area sought (i.e., facial expressions) led to the following number of published papers: *Science Direct* (81 papers), *PubMed* (27 papers), and *PsycINFO* (23 papers). Since *Google Scholar* did not allow the searching of terms within the abstracts or keywords in the papers, the terms used were searched within the titles of the articles. This led to 39 papers, resulting in a total of 170 papers when the database searches were combined. After collating the results of the different databases to check for duplicated papers, eliminating unrelated papers, and adding new papers cited in the ones selected, the final number of selected papers was 13 (see Table 1 for more details).

Table 1. List of the included studies.

| Authors[1] | Topic | Task used | Sample size[2] |
|---|---|---|---|
| Doi (2009) | Gaze and face direction effects | TBT | 11 |
| Droit-Volet (2004) | General emotional effect | TBT | 37 |
| Effron (2006) | Embodiment effect | TBT | 39 |
| Fayolle (2014) | Stimuli dynamism effect | TBT | 104 |
| Gil (2007) | Age effect | TBT | 83 |
| Gil (2011) | General emotional effect | Mixed | 87 |
| Kliegl (2015) | Face direction effect | TBT | 50 |
| Lee (2011) | General emotional effect | TRT | 36 |
| Li (2015) | Stimuli Dynamism effect | TBT | 83 |
| Mondillon (2007) | Embodiment effect | TBT | 88 |
| Nicol (2013) | Age affect | TBT | 42 |
| Tipples (2008) | General emotional effect | TBT | 42 |
| Tipples (2011) | General emotional effect | TBT | 46 |

Note. [1]For clarity's sake, only the first author is mentioned in the table; [2]For clarity's sake, when several experiments were included in the paper, the sum of the total sample is reported in this column.

## Results

### *General emotional effect*

The studies examining emotional expressions all showed an overestimation of time duration when confronted with facial expressions, especially when these pictured anger (e.g., Droit-Volet et al., 2004; Lee et al., 2011; Tipples, 2008, 2011). Several studies explored this interaction in depth. Gil and Droit-Volet (2011) investigated if the lengthening effect was present independently of the temporal task used. Here, 17 or 18 participants were allocated per temporal task (i.e., bisection task, generalization task, verbal estimation task, production task, and reproduction task; $n$ = 87). Their results showed that angry faces lengthened the estimation duration only in the bisection, verbal estimation, and production tasks compared to the neutral face. The authors reasoned that the lack of effect in the generalization task resulted from its structure. Indeed, the participants had to memorize a previously shown duration, and compare new stimuli lengths to this duration. As memory was based on a neutral stimulus, it could have minimized the impact of emotion for other stimuli. Alternatively, the lack of significant results in the reproduction task, compared to verbal estimation and production tasks, might have been due to working memory overload, numbing the picture's arousing effect.

Other variables found to influence the interaction between time perception and emotional faces included (i) stimuli dynamism (static pictures or animated ones), (ii) stimulus direction (straight or averted gaze), (iii) embodiment (ability to mimic someone's emotional state), and (iv) age (children vs. the elderly).

*Stimuli dynamism effect*

Most studies have used static face stimuli, whereas in real life, human faces are dynamic. Two studies explored the impact of dynamic faces to examine how this affected time perception. The first study explored whether an animated face shifting from a neutral expression into an angry or sad expression impacted time perception more intensively than a static face showing the same emotions (Fayolle & Droit-Volet, 2014). In the first experiment, participants (*N* = 104) performed a Temporal Bisection Task (TBT, 400-1600ms) in four groups varying in dynamism (static vs. dynamic) or emotion (sadness vs. anger). Each participant compared emotional expressions to neutral ones. Although there was no difference in perceived pleasantness between static and dynamic angry faces, and a lower level of perceived arousal for dynamic sad faces compared to static ones, dynamism significantly influenced the results. Specifically, in the static group, only angry faces were overestimated, whereas both emotional expressions were overestimated in the dynamic group. The second experiment directly compared the sad and angry faces, including the dynamism influence. Here, 84 participants performed the same bisection task, but in just two groups (dynamic vs. static) with no neutral faces included. The findings demonstrated that the presentation of angry faces was estimated as lasting longer than that of sad faces, with the effect being stronger in the dynamic group.

A second study exploring dynamism also included two experiments, the first one exploring more emotions and including both sexes in the expression faces' models (Li & Yuen, 2015). In the first experiment, participants (*N* = 44) performed a TBT (400-1600ms) while processing emotional expressions (i.e., neutral, happy, sad, and angry) either dynamically or statically. Additionally, models expressing the emotions were either male or female. The results demonstrated that sex had no impact, whereas the effects of dynamism were significant. While static expressions did not differ significantly from neutral expressions, the three morphing emotions did, with angry expressions being the most overestimated. To ensure the results in the dynamic group were not solely due to the morphing and emotions, a second experiment used the same procedure (*N* = 39), with the exception that instead of going from a neutral expression to an emotional one, the faces switched between two expressions (i.e., both emotional). The results showed that switching to happy or angry emotions lengthened the duration, thus excluding the sole effect of morphing found in the previous experiment.

*Gaze and face direction effects*

Gaze or face direction can also affect the relationship between an emotional expression and how long an individual appears to perceive this expression to last. Indeed, an averted gaze (i.e., an individual in front of participants looking away in another direction) would mean that the emotion depicted is not directed toward the participants. Therefore, it could be expected that the effect of emotion on the participant's time perception would be lessened. In a study by Doi and Shinohara (2009), participants (*N* = 11) performed a TBT (600-1400ms) while observing both happy and angry faces with either straight or averted gaze. Results demonstrated a main effect of gaze, with duration being estimated as longer when gaze was straight than when averted. There was no effect of expressions, but an interaction with gaze. Straight gaze was estimated to be longer than the averted one under an angry expression, but not for the happy expression. The explanation provided by the author for the lack of gaze effect on the happy expressions lay within a fight-or-flight effect. When an individual observes someone's face expressing anger, this will only be relevant if the expression is directed toward the individual (i.e., in order to properly prepare for the potential aggression). However, in the case of a happy emotion, whether the emotion is directed toward the individual or not does not trigger this type of fight-or-flight effect. Nonetheless, these results and interpretations should be taken cautiously because the number of participants in the study was low for this type of analysis (i.e., *n* = 11).

Kliegl et al. (2015) tried to extend these results by including three different face directions (i.e., 0°, 45°, 90°), comparing different emotions (i.e., angry, sad, and neutral), and comparing gender more systematically (i.e., same or opposite gender). Here, participants (*N* = 50) performed a TBT (400-1600ms) in four groups (according to gender comparison). The results showed a main effect of emotion, with only angry faces being overestimated (sad faces showing no difference in comparison to neutral faces). There was also a main effect of gender, with females judging presentation of male faces as lasting longer and vice-versa. Thus, face direction influenced the estimation of angry faces (i.e., reducing the effect of expression when the model was not facing the participant), but not for sad faces.

*Embodiment effect*

These aforementioned studies on gaze included different genders for the models and were based on the embodiment effect, where participants unconsciously imitate the person in front of them. Effron et al. (2006) examined whether individuals with inhibited facial expressions (i.e., by individuals holding a pen in their mouths) would still present an affected time perception when confronted with emotional expressions. Participants (*N* = 39, half in the inhibition group) performed a TBT (400-1600ms) while viewing either neutral, happy, or angry faces. Results showed a main effect of emotion and condition as well as an interaction between them. In the imitation group, participants overestimated duration of both angry and happy faces, with angry faces being the most overestimated. However, participants holding a pen in their mouth did not exhibit any difference between neutral and emotional faces.

In another study, Mondillon and colleagues (2007) explored the effects of embodiment on the interaction between emotion and time perception by confronting their participants with another ethnic group. The study comprised two experiments, one including Caucasian participants (*N* = 47) observing

Chinese faces, and the other including Chinese participants ($N$ = 41) observing Caucasian faces. In both experiments, participants performed a TBT (4001600ms) while processing either angry or neutral faces. When the participants were confronted with the same ethnic group, there was an effect of emotion and an interaction between emotion and duration where the angry faces were more overestimated in longer durations. When confronted with a different ethnic group, Caucasians showed neither an effect of emotion nor any interaction with duration. However, Chinese participants still exhibited an effect of emotion when observing Caucasians, possibly because the Chinese participants had been living in France and therefore had more exposure to other ethnic faces than the Caucasian participants in this study.

*Age effect*

Another variable affecting time perception is age. Studies have shown that time perception differs among children (e.g., Droit-Volet et al., 2001; Droit-Volet et al., 2006) and the elderly (e.g., Coelho et al., 2004; Ferreira et al., 2016) compared to younger adults. It is also thought that emotion can affect these groups differently (e.g., Gil, et al., 2007; Nicol et al., 2013). One study tested children from different age groups, as well as observing how emotional expressions affected their time perception (Gil et al., 2007). The experiment included 3-year-olds ($n$ = 26), 5-years-old ($n$ = 30), and 8-year-olds ($n$ = 27) who were tested using a TBT (400-1600 and 600-2400ms) with both neutral and angry facial expressions. Although the results did not show a main effect of age, there was an interaction with duration showing that children became more sensitive to time as they got older (i.e., they exhibited less variable time perception). However, there was a main effect of emotion with angry faces being overestimated compared to neutral faces. Thus, there was no interaction with age, demonstrating that emotional expressions did not affect children differently.

In relation to elderly people (65-85-years in the studies explored), studies show that they tend to focus more on positive emotions rather than negative ones (Carstensen & Mikels, 2005). Based on this fact, it was assumed that positive emotions would show a stronger interference among older participants because they would focus more on these emotions. Along the same lines, it was expected that younger participants would exhibit the opposite effect (i.e., stronger effect of negative emotions). Nicol and colleagues (2013) recruited 20 young adult participants (mean age = 22.3 years) and 22 older adult participants (mean age = 67.6 years) who performed a TBT (400-1600ms) including four types of expression stimuli (i.e., angry, sad, happy, and neutral). All participants completed the Positive and Negative Affect Scale (Watson et al., 1988) to assess their level of negativity or positivity. As expected, older adults had higher scores for positive affect while younger adults had higher scores for negative affect. Furthermore, older adults were more aroused by positive pictures than younger adults (i.e., on a scale from 1 to 5), with young adults being marginally more aroused by negative pictures. There was also an effect of emotional expression, but no main effect of age, even if the latter interacted significantly with emotional expressions. Positive expressions were estimated to last longer for older adults, although younger adults did not judge negative expressions to last longer than older participants. Analysed separately, young adults estimated angry expressions as longer than neutral expressions, with older adults showing this effect for happy and negative expressions only.

## Discussion

The reviewed papers highlighted that emotional expressions, especially anger, lead to overestimation of time duration, explained as either due to arousal or attentional effects. The arousal effect of the stimuli leads to an acceleration of the pacemaker rate, which in turn increases the number of pulses recorded, resulting in overestimation of duration. Alternatively, the attentional effect is explained via the SET model, the picture triggering the switch to remain open longer, leading to higher accumulation of pulses. The differentiation of these two processes would then be mathematical:

(i) an increase in pacemaker speed (i.e., arousing effect) leads to a multiplicative effect: the longer the duration of the arousing stimulus, the more pulses are recorded.
Or

(ii) A trigger of the switch (i.e., attentional effect) leads to an additive effect because only a few extra pulses would go through.

However, this mathematical method for differentiating the two processes would require experiments to have used several durations, and only three studies did this: two studies found an additive effect (i.e., attentional effect; Gil & Droit-Volet, 2011; Lee et al., 2011) and one study showed a multiplicative effect (i.e., arousing effect, Droit-Volet et al., 2004). However, Gil and DroitVolet (2011) noted that because faces are processed in under 200ms, their arousing effect may not be observable (i.e., the participants would be aroused for too short a duration for it to affect their time perception), and that a multiplicative effect would require longer durations to be effective.

Although this observation appears to indicate that emotional face interference is the result of an attentional effect, several authors have argued that there can be an arousal effect, basing their explanation on the type of emotion depicted by the faces. Indeed, most studies reported aggressive expressions (i.e., anger) were more overestimated than other expressions (e.g., sadness or happiness), which could be directly due to their arousing nature (i.e., fight-or-flight response; Fayolle & Droit-Volet, 2014; Li & Yuen, 2015; Nicol et al., 2013; Tipples, 2008, 2011). This is supported by studies exploring the effect of gaze or face direction, as both of these studies showed that when aggressive stimuli were not directed towards participants (i.e., model looking in another direction), the lengthening effect was nullified (Doi & Shinohara, 2009; Kliegl et al., 2015). If the threat is not directed at participants, they have no reason to feel threatened, which explains the absence of overestimation.

Interestingly, two studies raised the possibility of an interaction between attention and arousal in explaining the interference of emotional expressions on time perception (Fayolle & Droit-Volet, 2014; Li & Yuen, 2015). Here, the studies observed that dynamic faces showed increased interference compared to static ones. Although the angry faces were still overestimated more than the sad ones (indicating an arousal effect), other results also indicated an attentional effect. For example, Fayolle and Droit-Volet (2014) showed that while there was an increased effect amongst dynamic faces, when participants were asked to rate the arousal level of the stimuli, they did not judge dynamic ones as more arousing than static ones. This shows that increase in overestimation is an attentional effect. Li and Yuen (2015) found that when a face morphed between two different levels of arousal with the same valence (e.g., sadness and anger), the increase in overestimation was lower than when it morphed between two emotions with a different valence (e.g., anger to happiness). Again, this effect tends to suggest that although arousal has an effect, it is not the only mechanism at stake, because a change in valence triggers an attentional effect.

From these studies, a number of conclusions can be drawn. Several hypotheses have been proposed to interpret the effect of facial expressions on time perception, although all relate to whether the effect is attention-based or arousal-based. The most plausible explanation appears to be an interaction of emotion and attention, as noted in morphing studies (Fayolle & Droit-Volet, 2014; Li & Yuen, 2015). However, further experiments are required to understand how emotional expressions lead to an overestimation of time duration, and to confirm whether or not there is an interaction of arousal and attentional effects. These results are of particular interest in understanding how time perception fluctuates in real life, because facial expressions are among the most important stimuli in social interactions.

The findings show interesting research possibilities in the field of social cognition, as a few social elements tend to affect time perception (i.e., an overestimation of time is observed), such as the embodiment or the positivity effect. Therefore, time perception could be a great tool for evaluating the effect of social variables on cognition (e.g., interacting with someone aggressive or sympathetic). Indeed, as time perception appears to be sensitive to social variables, it could make it easier to observe how they impact cognition via time estimation fluctuation (i.e., observing an underestimation or overestimation).

**References**

Block, R. A. (2003). Psychological timing without a timer: The roles of attention and memory. In *H. Helfrich(Ed.), Time and mind II: Information processing perspectives*. Ashland, OH: Hogrefe & Huber.

Block, R. A., Hancock, P. A., & Zakay, D. (2010). How cognitive load affects duration judgments: A meta-analytic review. *Acta Psychologica*, *134*(3), 330–343. https://doi.org/10.1016/j.actpsy.2010.03.006

Block, R. A., & Reed, M. A. (1978). Remembered duration: Evidence for a contextual-change hypothesis. *Journal of Experimental Psychology: Human Learning and Memory*, *4*(6), 656–665. https://doi.org/10.1037/0278-7393.4.6.656

Carstensen, L. L., & Mikels, J. A. (2005). At the Intersection of Emotion and Cognition: Aging and the Positivity Effect. *Current Directions in Psychological Science*, *14*(3), 117–121. https://doi.org/10.1111/j.0963-7214.2005.00348.x

Coelho, M., Ferreira, J. J., Dias, B., Sampaio, C., Martins, I. P., & Castro-Caldas, A. (2004). Assessment of time perception: The effect of aging. *Journal of the International Neuropsychological Society*, *10*(3), 332–341. https://doi.org/10.1017/S1355617704103019

Doi, H., & Shinohara, K. (2009). The perceived duration of emotional face is influenced by the gaze direction. *Neuroscience Letters*, *457*(2), 97–100. https://doi.org/10.1016/j.neulet.2009.04.004

Droit-Volet, S., Brunot, S., & Niedenthal, P. (2004). Perception of the duration of emotional events. *Cognition and Emotion*, *18*(6), 849–858. https://doi.org/10.1080/02699930341000194

Droit-Volet, S., Clément, A., & Wearden, J. (2001). Temporal generalization in 3- to 8-yearold children. *Journal of Experimental Child Psychology*, *80*(3), 271–288. https://doi.org/10.1006/jecp.2001.2629

Droit-Volet, S., Delgado, M., & Rattat, A.-C. (2006). The development of the ability to judge time in children. In Marrow, J. R. (Ed.), *Focus on child psychology research* (pp. 81–104). Hauppage, NY: Nova Science.

Effron, D. A., Niedenthal, P. M., Gil, S., & Droit-Volet, S. (2006). Embodied temporal perception of emotion. *Emotion*, *6*(1), 1–9. https://doi.org/10.1037/1528-3542.6.1.1

Fayolle, S., & Droit-Volet, S. (2014). Time perception and dynamics of facial expressions of emotions. *PloS ONE*, *9*(5), e97944. https://doi.org/10.1371/journal.pone.0097944

Fayolle, S., Droit-Volet, S., & Gil, S. (2014). Emotion and time perception: Effects of filminduced mood. *Procedia - Social and Behavioral Sciences*, *126*, 251–252. https://doi.org/10.1016/j.sbspro.2014.02.399 Ferreira, V. F. M., Paiva, G. P., Prando, N., Graça, C. R., & Kouyoumdjian, J. A. (2016). Time perception and age. *Arquivos de Neuro-Psiquiatria*, *74*(4), 299–302. https://doi.org/10.1590/0004-282X20160025 Gibbon, J., Church, R. M., & Meck, W. H. (1984). Scalar timing in memory. *Annals of the New York Academy of Sciences*, *423*, 52–77.

Gil, S., & Droit-Volet, S. (2011). “Time flies in the presence of angry faces”… depending on the temporal task used! *Acta Psychologica*, *136*(3), 354–362. https://doi.org/10.1016/j.actpsy.2010.12.010 Gil, S., Niedenthal, P. M., & Droit-Volet, S. (2007). Anger and time perception in children. *Emotion*, *7*(1), 219–225. https://doi.org/10.1037/1528-3542.7.1.219

Kliegl, K. M., Limbrecht-Ecklundt, K., Dürr, L., Traue, H. C., & Huckauf, A. (2015). The complex duration perception of emotional faces: Effects of face direction. *Frontiers in Psychology*, *6*, 262. https://doi.org/10.3389/fpsyg.2015.00262

Lee, K.-H., Seelam, K., & O’Brien, T. (2011). The relativity of time perception produced by facial emotion stimuli. *Cognition & Emotion*, *25*(8), 1471–1480. https://doi.org/10.1080/02699931.2010.544455

Levin, I., & Zakay, D. (1989). *Advances in psychology, 59. Time and human cognition: A lifespan perspective*. Oxford, England: North-Holland.

Li, W. O., & Yuen, K. S. L. (2015). The perception of time while perceiving dynamic emotional faces. *Frontiers in Psychology*, *6,* 1248. https://doi.org/10.3389/fpsyg.2015.01248

Lobmaier, J. S., & Fischer, M. H. (2015). Facial feedback affects perceived intensity but not quality of emotional expressions. *Brain Sciences*, *5*(3), 357–368. https://doi.org/10.3390/brainsci5030357

Mondillon, L., Niedenthal, P. M., Gil, S., & Droit-Volet, S. (2007). Imitation of in-group versus out-group members’ facial expressions of anger: A test with a time perception task. *Social*

*Neuroscience*, *2*(3–4), 223–237. https://doi.org/10.1080/17470910701376894 Nicol, J. R., Tanner, J., & Clarke, K. (2013). Perceived duration of emotional events: Evidence for a positivity effect in older adults. *Experimental Aging Research*, *39*(5), 565–578. https://doi.org/10.1080/0361073X.2013.839307

Tipples, J. (2008). Negative emotionality influences the effects of emotion on time perception. *Emotion*, *8*(1), 127–131. https://doi.org/10.1037/1528-3542.8.1.127

Tipples, J. (2011). When time stands still: Fear-specific modulation of temporal bias due to threat. *Emotion*, *11*(1), 74–80. https://doi.org/10.1037/a0022015 Treisman, M. (1963). Temporal discrimination and the indifference interval: Implications for a model of the" internal clock". *Psychological Monographs: General and Applied*, *77*(13), 1–31. http://psycnet.apa.org/doi/10.1037/h0093864

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070. http://dx.doi.org/10.1037/0022-3514.54.6.1063

Xie, W., & Zhang, W. (2017). Negative emotion enhances mnemonic precision and subjective feelings of remembering in visual long-term memory. *Cognition*, *166*(Supplement C), 73–83. https://doi.org/10.1016/j.cognition.2017.05.025

Zakay, D., & Block, R. A. (1995). An attentional-gate model of prospective time estimation. In *M. Richelle, V. D. Keyser, G. D. Ydeualle, & A. Vandierendonck (Eds.), Time and the dynamic control of behavior* (pp. 167–178). Liege, Belgium: University of Liege Press.

Zlomuzica, A., Preusser, F., Totzeck, C., Dere, E., & Margraf, J. (2016). The impact of different emotional states on the memory for what, where and when features of specific events. *Behavioural Brain Research*, *298*(Part B), 181–187. https://doi.org/10.1016/j.bbr.2015.09.037