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The Temporal Dimension of Trust: Investigating the Influence of Facial Trustworthiness on Time Perception

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Abstract

Time perception plays a crucial role in human cognition and social interactions. While research has explored how emotional facial expressions influence time perception, the impact of facial trustworthiness remains unexplored. This study investigates the effect of facial trustworthiness on time perception using a temporal bisection task. Eighty-two participants were presented with computer-generated faces varying in trustworthiness levels, displayed for durations between 2 and 5 seconds. Participants categorized these durations as "short" or "long" relative to learned standards. A manipulation check validated the perceived trustworthiness of the stimuli. The study aimed to determine whether and how facial trustworthiness influences subjective time perception. Results revealed a significant main effect of facial trustworthiness on time perception, with more trustworthy faces associated with shorter perceived durations. This effect was most pronounced for intermediate durations (3-4 seconds). Analysis of the Point of Subjective Equality (PSE) further supported these findings. The study concludes that facial trustworthiness can subtly but significantly modulate time perception, suggesting a complex interplay between social cognition and temporal processing. These findings have implications for understanding social decision-making in time-sensitive contexts and contribute to our knowledge of how social cues influence fundamental cognitive processes.

Keywords: time perception, facial trustworthiness, social cognition, temporal bisection task, manipulation check

1. Introduction

The perception of time, a fundamental aspect of human cognition, profoundly influences our interactions with the world and our social environment. In recent years, there has been a growing interest with the adaptability of of time perception, particularly in response to social and emotional cues (Droit-Volet & Meck, 2007; Lake, LaBar, and Meck, 2016). While substantial research has explored how emotional facial expressions modulate temporal judgments, the specific impact of facial trustworthiness—a rapidly processed and influential dimension of social cognition—on time perception remains a largely unexplored area in cognitive psychology.

Time perception has been extensively studied through various theoretical frameworks, each offering unique insights into the mechanisms underlying our subjective experience of time. Internal clock models, such as the Scalar Expectancy Theory (SET) proposed by Gibbon, Church, and Meck (1984), posit a pacemaker-accumulator mechanism for time perception. Cognitive models, including Zakay and Block's (2004) Attentional-Gate Model, emphasize the role of attention and memory processes in temporal judgments. Neuroscientific perspectives have also clarified the neural substrates involved in time perception, implicating regions such as the basal ganglia, cerebellum, and prefrontal cortex (Wiener, Turkeltaub, & Coslett, 2010). These diverse approaches provide a comprehensive theoretical framework against which to examine the potential influence of social cues on temporal cognition.

Concurrently, research on facial trustworthiness has revealed its evolutionary significance and its rapid, often unconscious influence on social decision-making (Todorov, Baron, & Oosterhof, 2008). Trustworthiness judgments from faces occur within milliseconds of exposure (Willis & Todorov, 2006) and have been shown to impact a wide range of social behaviors and judgments. The neural underpinnings of trustworthiness perception, particularly the involvement of the amygdala and insula, suggest a potential link to emotional and interoceptive processes that are also implicated in time perception (Knutson, 2020).

The intersection of time perception and facial trustworthiness presents an intriguing area for investigation, with potential implications for understanding the complex relationship between social cognition and basic perceptual processes. While numerous studies have examined how emotional facial expressions affect time perception (e.g., Droit-Volet, Brunot, & Niedenthal, 2004; Tipples, 2008), there is a notable gap in our understanding of how more detailed social cues, such as perceived trustworthiness, might influence temporal judgments. Trustworthiness, as a social dimension, may operate through different mechanisms than basic emotions, potentially engaging more complex cognitive processes that could uniquely impact time perception.

This thesis aims to bridge this gap by investigating the influence of facial trustworthiness on time perception using a temporal bisection task. Specifically, we will explore how varying levels of facial trustworthiness affect participants' judgments of stimulus duration. By systematically manipulating trustworthiness levels in computer-generated faces and presenting them for various durations, we seek to uncover the nature and extent of trustworthiness's effect on temporal cognition.

The study utilizes a precise experimental design, presenting participants with a series of facial stimuli varying in trustworthiness, displayed for durations ranging from 2 to 5 seconds. This duration range is particularly relevant as it aligns with the cognitive timing mechanisms proposed by Lewis and Miall (2003), allowing us to examine how social cognitive processes might interact with time perception in a range that is neither too brief for conscious evaluation nor too long to maintain focused attention. Participants will categorize these durations as either "short" or "long" relative to learned standards.

Our analytical approach will focus on examining potential shifts in the point of subjective equality (PSE) across trustworthiness levels, providing insights into how facial trustworthiness might bias time perception. We will employ mixed-effects modeling to account for individual differences and potential hierarchical structures in our data, allowing for a more precise understanding of the relationship between facial trustworthiness and temporal judgments.

Additionally, we will conduct a manipulation check to validate the perceived trustworthiness of our stimuli, ensuring the effectiveness of our trustworthiness manipulation. This multi-faceted approach, combining behavioral measures with explicit trustworthiness ratings, will enable us to draw more robust conclusions about the relationship between facial trustworthiness and time perception.

We anticipate that our findings will reveal a significant effect of facial trustworthiness on time perception, potentially manifesting as a tendency to underestimate durations for more trustworthy faces. Such a result would suggest that trustworthiness, as a social cue, can modulate basic perceptual processes in ways distinct from more overt emotional expressions. These findings could have important implications for understanding social decision-making, particularly in time-sensitive contexts.

The potential outcomes of this study could contribute significantly to several areas of psychological science. In the realm of social cognition, our findings may shed light on the pervasive influence of trustworthiness judgments, extending their known effects to the domain of basic perceptual processes. For time perception research, this study may reveal new factors that influence subjective time, potentially leading to refinements in existing models of temporal cognition. From a neuroscientific perspective, our results may suggest new avenues for investigating the neural correlates of social influence on time perception, possibly implicating regions involved in both trustworthiness evaluation and temporal processing.

Moreover, the findings of this study could have broad-reaching practical implications. In forensic and legal contexts, our results may provide insights into how perceptions of trustworthiness might inadvertently influence eyewitness testimonies or juror decisions, especially when temporal judgments are involved.

By exploring this novel intersection of social cognition and time perception, this thesis aims to contribute to our understanding of how social information processing interacts with fundamental cognitive mechanisms. The results of this study may open new avenues for research in social psychology, cognitive neuroscience, and decision-making.

In the subsequent chapters, we will provide a comprehensive review of the relevant literature, detailing our experimental methods, presenting our findings, and discussing their implications within the broader context of cognitive and social psychology. Through this work, we aim to advance our understanding of the complex interplay between social perception and temporal cognition, offering new insights into the complicated workings of the human mind.

2. Literature Review: The Interplay of Facial Trustworthiness and Time Perception

2.1. Theories of Time Perception

The study of time perception has yielded various theoretical models attempting to explain how humans and animals perceive and estimate time intervals. Three primary approaches can be used to broadly categorize these theories: internal clock models, cognitive models, and neuroscientific perspectives.

2.1.1 Internal Clock Models

Internal clock models posit that time perception is regulated by an internal mechanism that functions similarly to a clock. The Scalar Expectancy Theory (SET) is the most influential of these, having been initially proposed by (Gibbon, 1977) and subsequently developed by Gibbon, Church, and Meck (1984). SET postulates a timing mechanism comprising three key components: a pacemaker that emits regular pulses, an accumulator that counts these pulses, and a comparator that contrasts the accumulated pulses with a stored reference memory (Gibbon et al., 1984).

The study of SET has played a crucial role in clarifying a range of phenomena related to time perception, particularly the scalar property of timing. This property refers to the observation that the standard deviation of time estimates is proportional to the mean, resulting in a constant coefficient of variation across various time scales (Wearden & Lejeune, 2008). Consistent observations of the scalar property have been documented in timing investigations conducted on both animals and humans, hence offering strong evidence in support of the SET model.

The Striatal Beat Frequency (SBF) theory, proposed by Matell and Meck (2004), represents an advancement of the SET framework. The SBF theory posits that timing arises from the coincidental activation of cortical neurons, which is detected by striatal spiny neurons. This theoretical framework serves to reconcile the gaps between cognitive models and neurobiological mechanisms, offering a more biologically plausible explanation for the internal clock. In the study conducted by Matell and Meck (2004), it was found that cortical neurons exhibit oscillations at varying frequencies, which function as the clock mechanism. Additionally, the striatum is identified as a coincidence detector for these oscillatory patterns.

Recent research has integrated these internal clock models with broader cognitive architectures. Taatgen, van Rijn, and Anderson (2007) incorporated a timing mechanism into the Adaptive Control of Thought-Rational (ACT-R) cognitive architecture. The present integration serves as an illustration of the interplay between time perception and other cognitive processes. The ACT-R model posits that temporal information is stored in declarative memory, and the retrieval of these temporal memories is susceptible to decay and interference, hence impacting the accuracy of time estimation. The proposed approach utilizes a temporal module to determine the appropriate timing for responding in timing tasks. This process involves comparing the current time estimate with the stored temporal information. Furthermore, the model accounts for how divided attention affects time perception, explaining phenomena like the attentional gate in timing tasks (Taatgen et al., 2007).

This integrated approach highlights how time perception is not an isolated process but is deeply interconnected with other cognitive functions, providing a more comprehensive understanding of temporal cognition. The ACT-R model's predictions demonstrate a strong agreement with empirical data obtained from a range of timed tasks, including both production and estimation paradigms (Taatgen et al., 2007).

The development of these models represents significant progress in our understanding of time perception. Nonetheless, there are still obstacles to overcome when attempting to fully reconcile cognitive models with neurobiological findings, particularly in explaining individual differences in timing abilities and the influence of emotional and contextual factors on time perception.

2.1.2 Cognitive Models of Time Perception

Cognitive models of time perception place significant emphasis on the contributions of attention, memory, and various cognitive processes in shaping human experience and estimation of time. These models hold significant relevance in comprehending time perception within complex, real-life situations where numerous cognitive processes interplay.

Zakay and Block's (2004) Attentional-Gate Model builds upon the internal clock model by proposing that attention acts as a gate between the pacemaker and accumulator. The model suggests that the allocation of greater attention to time results in an increased number of pulses passing through the gate, hence causing longer time estimations. The Attentional-Gate Model provides a framework for understanding how non-temporal tasks can interfere with time perception, a phenomenon often observed in dual-task paradigms (Brown, 1997). For instance, Brown (1997) demonstrated that engaging in a concurrent non-temporal task, such as visual search or mental arithmetic, can lead to shorter and more variable time estimates, supporting the idea that attention plays a pivotal role in time perception.

The Storage Size Model proposed by Ornstein (1969) presents an alternative viewpoint, suggesting that the perceived duration of an interval depends on the quantity and complexity of information processed during that interval. This model is consistent with the common experience of time seeming to pass more quickly when engaged in complex or engaging tasks. Ornstein's model has been influential in explaining phenomena such as the "time flies when you're having fun" effect and has inspired further research into the relationship between cognitive load and time perception.

The impact of cognitive load on time perception has been a subject of extensive research, providing crucial insights into the cognitive mechanisms underlying temporal judgments. A comprehensive meta-analysis by Zakay et al. (2004) revealing that cognitive load affects duration judgments differently depending on whether they are prospective (known in advance) or retrospective (unexpected). In prospective paradigms, increased cognitive load consistently led to shorter duration estimates, supporting attentional models of timing such as the Attentional-Gate Model (Zakay et al., 2004). Conversely, in retrospective paradigms, higher cognitive load tended to result in longer duration estimates, aligning with memory-based models like Ornstein's (1969) Storage Size Model. The study also found that the variability of duration judgments, as measured by the coefficient of variation, increased under high cognitive load in prospective, but not retrospective, timing tasks.

Contemporary cognitive approaches have focused on the role of predictive processing in time perception. The Bayesian models of time perception, as discussed by Shi, Church, and Meck (2013), propose that the brain combines prior expectations about duration with sensory evidence to estimate time intervals. This approach can account for various contextual effects on time perception, such as the influence of rhythmic structures or temporal expectations.

For instance, the study conducted by Jazayeri and Shadlen (2010), as cited in the work of Shi et al. (2013), provided evidence of the applicability of Bayesian inference in elucidating the central tendency effect observed in time reproduction tasks. Participants in the study were instructed to reproduce time intervals drawn from various distributions. The findings indicated that reproductions were biased towards the mean of the distribution, consistent with the Bayesian framework's prediction that prior knowledge (in this case, the distribution of intervals) influences time estimation.

One more illustration of how Bayesian models elucidate contextual effects is the impact of rhythmic structures on time perception. In a study conducted by Rohenkohl and Nobre (2011), it was observed that participants exhibited higher levels of accuracy in recognizing targets when they were presented at time points that aligned with a previously established rhythm. The results of this study are consistent with the Bayesian perspective, suggesting that the brain forms temporal expectations based on rhythmic patterns, which then influence the perception of subsequent time intervals.

The Bayesian approach to time perception also offers insights into how the brain might optimize temporal judgments in the face of uncertainty. Acerbi, Wolpert, and Vijayakumar (2012) showed that participants' behavior in a time estimation task was consistent with Bayesian decision theory, with participants automatically adjusting their temporal judgments to minimize error given the inherent uncertainty in their time estimates.

These cognitive models of time perception provide complementary perspectives on how the brain processes temporal information. While the Attentional-Gate Model focuses on the role of attention in modulating the internal clock, the Storage Size Model emphasizes the impact of information processing on perceived duration. The Bayesian approach, in turn, offers a framework for understanding how the brain integrates prior knowledge with sensory input to make optimal temporal judgments.

By considering these diverse cognitive models, researchers can develop a more comprehensive understanding of time perception that accounts for the complex interplay between attention, memory, information processing, and predictive mechanisms in the brain. This multifaceted approach is essential for explaining the wide range of temporal phenomena observed in both laboratory settings and everyday life.

2.1.3 Neuroscientific Perspectives on Time Perception

Neuroscientific research has identified several brain regions and neural mechanisms involved in time perception, providing a biological basis for the theoretical models discussed above.

The basal ganglia and cerebellum have been consistently implicated in timing processes, particularly for intervals in the range of seconds to minutes (Ivry & Spencer, 2004). The basal ganglia are thought to be crucial for interval timing, aligning with the striatal beat frequency (SBF) theory. According to the SBF model, timing is mediated by the coincidence detection of oscillatory activity in cortico-striatal circuits (Matell & Meck, 2004). The cerebellum is more involved in precise timing of motor actions and may play a role in duration discrimination tasks, especially for sub-second intervals. Ivry and Spencer (2004) propose that the cerebellum is involved in event timing, while the basal ganglia mediate emergent timing processes.

Neuroimaging studies have revealed a distributed network of brain regions involved in time perception, including the supplementary motor area (SMA), prefrontal cortex, and posterior parietal cortex (Wiener, Turkeltaub, & Coslett, 2010). Wiener et al. (2010) conducted a comprehensive meta-analysis of neuroimaging studies on timing and found that the SMA and right inferior frontal gyrus were the only regions consistently activated across all timing tasks. The specific involvement of these regions often depends on the nature of the timing task and the duration of the interval being estimated. For example, sub-second timing tasks were more likely to activate subcortical structures like the basal ganglia and cerebellum, while supra-second tasks engaged more cortical areas like the prefrontal cortex.

Recent research has also highlighted the role of neural oscillations in time perception. Kononowicz and van Rijn (2015) found that the amplitude of beta oscillations (15-30 Hz) in the SMA correlates with subjective time estimates, providing a potential neural substrate for the accumulation process proposed in internal clock models. Specifically, they showed that higher beta power after the onset of an interval predicted longer time productions. This suggests that beta oscillations may index the subjective experience of time passing and could be linked to the accumulation of temporal information.

Dopaminergic signaling has been shown to play a crucial role in timing processes, with dopamine agonists leading to overestimation of time intervals and antagonists causing underestimation (Coull, Cheng, & Meck, 2011). This finding has important implications for understanding timing deficits in conditions affecting the dopaminergic system, such as Parkinson's disease. Coull et al. (2011) review evidence from pharmacological studies in both animals and humans demonstrating the key role of dopamine in modulating internal clock speed. They propose that dopamine may influence timing through its effects on neural oscillations in cortico-striatal circuits, potentially by modulating the frequency of oscillators in the SBF model.

The authors also discuss how different cognitive processes involved in timing, such as attention and working memory, are subserved by distinct neural systems. For example, right prefrontal cortex appears to be involved in working memory processes supporting timing of longer durations, while left parietal cortex is implicated in attentional orienting to predictable moments in time. This highlights the complex and distributed nature of the neural systems underlying time perception.

2.2. Emotional Influences on Time Perception

The interaction between emotion and time perception has been a subject of increasing interest, revealing that our emotional states and the emotional content of stimuli can significantly alter our perception of time.

2.2.1 Arousal and Valence Effects

Research has consistently shown that emotional stimuli are often perceived as lasting longer than neutral stimuli of the same objective duration. This effect is typically explained through the lens of internal clock models, where increased arousal is thought to speed up the pacemaker, leading to more accumulated pulses and thus longer time estimates (Droit-Volet & Meck, 2007).

To provide clarity, it's important to define the key constructs of arousal and valence. Arousal refers to the intensity of an emotional response, ranging from calm to excited, while valence describes the pleasantness or unpleasantness of an emotional stimulus (Russell, 1980). These two dimensions are fundamental in understanding emotional experiences and their effects on cognitive processes, including time perception.

The effects of emotion on time perception are not uniform and can vary depending on the specific emotions involved. A meta-analysis by Lake, LaBar, and Meck (2016) found that while high-arousal stimuli generally lead to temporal overestimation, the effect of emotional valence (positive vs. negative) is less consistent and may interact with arousal levels. This complexity is further illustrated by studies examining specific emotional states. For instance, Tipples (2008) found that angry faces were perceived as lasting longer than neutral faces, suggesting a role for threat-related emotions in time distortion.

(Angrilli, Cherubini, Pavese, & Manfredini, 1997) proposed a dual-model of time perception for emotional events, suggesting that different mechanisms operate depending on the arousal level:

1. At high arousal levels, an attention-driven mechanism leads to the underestimation of negative events and overestimation of positive events.

2. At low arousal levels, an emotion-driven mechanism causes an overestimation of negative events and underestimation of positive events.

This model highlights the complex interplay between arousal, valence, and cognitive processes in emotional time perception. Subsequent research has both supported and challenged aspects of this model. For example, Noulhiane et al. (2007) found that emotional sounds were generally perceived as longer than neutral sounds, but negative sounds were judged as longer than positive ones, partially contradicting Angrilli's model.

The interaction between arousal and valence has been further explored in various contexts. Mella, Conty, and Pouthas (2011) investigated the role of physiological arousal in time perception using an emotion regulation paradigm. They found that when participants were instructed to decrease their emotional response, it led to reduced physiological arousal and shorter time estimations, supporting the link between arousal and perceived duration.

Moreover, the effects of emotion on time perception can vary depending on the temporal range being studied. Droit-Volet, Fayolle, and Gil (2011) examined how film-induced moods affected the perception of short (0.4-1.6 s) and longer (2-8 s) durations. They found that for short durations, both positive and negative emotional states led to time overestimation, while for longer durations, only negative states caused overestimation. This suggests that the mechanisms underlying emotional influences on time perception may differ for different time scales.

In conclusion, while increased arousal generally leads to longer time estimates, the effects of emotional valence are more nuanced and context-dependent. The dual-model proposed by Angrilli et al. (1997) provides a framework for understanding these effects, but ongoing research continues to refine our understanding of how emotions shape our perception of time. Future studies may benefit from considering not only arousal and valence but also specific emotional categories and the temporal range of the stimuli to gain a more comprehensive understanding of emotion-induced time distortions.

2.2.2 Emotion-Specific Effects

Different emotions appear to have distinct effects on time perception, likely due to their varying levels of arousal and evolutionary significance. Research has shown that specific emotions can modulate our subjective experience of time in unique ways:

Fear and Threat-Related Stimuli:

Fear and threat-related stimuli consistently lead to temporal overestimation, likely due to their high arousal and evolutionary significance (Fayolle, Gil, & Droit-Volet, 2015). This effect has a clear evolutionary advantage - in dangerous situations, perceiving time as moving more slowly allows for more time to process information and prepare an appropriate response. Fayolle et al. (2015) demonstrated this effect using a temporal bisection task with electric shocks as fear-inducing stimuli. They found that the expectation of an electric shock led to an overestimation of time intervals, with this effect being more pronounced for longer durations (400-1600 ms) compared to shorter ones (100-300 ms).

The evolutionary basis for this effect lies in the adaptive value of rapid threat detection and response. When faced with potential danger, an overestimation of time can provide a perceptual advantage, allowing individuals to feel as though they have more time to react. This temporal dilation may have been crucial for survival in our evolutionary past, enabling quicker decision-making and action in life-threatening situations.

Sadness:

Sadness has been associated with the subjective slowing of time, possibly due to decreased arousal and increased self-focus (Gil & Droit-Volet, 2009). In their study, Gil and Droit-Volet found that participants with higher depression scores tended to underestimate time durations in a temporal bisection task. This effect was more pronounced for longer durations, suggesting that the impact of sadness on time perception may be cumulative over time.

The researchers proposed that this underestimation might be related to a slowing down of the internal clock in depressed individuals, potentially linked to reduced dopaminergic activity. Additionally, the increased self-focus associated with sadness may divert attention away from external time cues, further contributing to the subjective slowing of time.

Happiness:

The effect of happiness on time perception is less consistent, with some studies showing overestimation (Droit-Volet, Brunot, & Niedenthal, 2004) and others showing underestimation (Smith, Mciver, Nella, & Crease Lark, 2011). This variability may be due to differences in arousal levels associated with different types of positive emotions.

Droit-Volet et al. (2004) found that happy facial expressions led to temporal overestimation in a temporal bisection task, similar to the effect seen with angry faces. They attributed this to increased arousal associated with emotional stimuli in general.

However, Smith et al. (2011) reported a more complex pattern. They found that high-arousal positive stimuli led to underestimation of time for longer durations (400-1600 ms), while low-arousal positive stimuli showed a tendency towards overestimation. This suggests that the arousal component of positive emotions plays a crucial role in determining their effect on time perception.

These conflicting results highlight the complexity of positive emotions and their effects on temporal cognition. Factors such as the specific type of happiness (e.g., excited joy vs. calm contentment), the intensity of the emotion, and the duration being judged may all contribute to the observed effects.

In conclusion, these emotion-specific effects on time perception underscore the intricate relationship between our emotional states and our subjective experience of time. They demonstrate how our perception of time is not a fixed, objective phenomenon, but rather a malleable experience influenced by our emotional context. Understanding these effects can provide insights into both the nature of temporal cognition and the broader impact of emotions on cognitive processes.

2.2.3 Embodiment and Time Perception

An intriguing line of research has explored the embodied nature of emotional influences on time perception. This work is grounded in theories of embodied cognition, which propose that cognitive processes are fundamentally grounded in the body's interactions with the world. According to these theories, our understanding of concepts, including emotions, involves partial re-enactments or simulations of bodily states associated with those concepts.

(Effron, Niedenthal, & Gil, 2006) conducted a pivotal study that demonstrated the role of embodiment in emotional influences on time perception. They used a temporal bisection task where participants had to categorize the duration of displayed facial expressions as either "short" or "long" compared to two learned standard durations. The key manipulation was that half of the participants held a pen between their lips and teeth, which inhibited facial mimicry, while the other half were free to mimic the facial expressions naturally.

The results showed that participants who were able to freely mimic the facial expressions exhibited the typical overestimation of duration for emotional faces (particularly angry faces) compared to neutral faces. However, this effect disappeared when facial mimicry was inhibited by the pen-holding task. These findings suggest that the mere activation of emotion-related motor programs through facial mimicry can influence temporal judgments, even when there is no explicit emotional experience present.

The present investigation offers robust evidence in favour of embodied cognition theories within the domain of time perception. This proposition posits that our perception of time is not solely a cognitive phenomenon, but rather intricately linked to our bodily states and actions. The act of mimicking an emotional expression seems to be sufficient to induce changes in time perception similar to those caused by actually experiencing the emotion.

Building on this work, (Mondillon, Niedenthal, Gil, & Droit-Volet, 2007) extended the investigation of embodied time perception by examining how the ethnicity of facial stimuli interacts with emotional expression to influence time perception. They used a similar temporal bisection task but included both Caucasian and Chinese facial stimuli expressing anger or neutral emotions.

Their findings revealed an intriguing in-group/out-group effect: Caucasian participants showed temporal overestimation for angry Caucasian faces but not for angry Chinese faces. This suggests that the embodied simulation process that underlies the influence of emotional expressions on time perception may be modulated by social factors such as group membership.

These results have important implications for our understanding of both time perception and social cognition. They suggest that our perception of time is not only influenced by the emotions we see in others but also by our social relationship to those individuals. The fact that participants did not show the same temporal distortion for out-group faces implies that the embodied simulation process may be automatically enhanced for in-group members.

Further evidence for the embodied nature of time perception comes from a study by (Chambon, Droit-Volet, & Niedenthal, 2008), which investigated how the perception of elderly faces influences temporal judgments. An investigation using a temporal bisection task revealed that participants interpreted durations as shorter when shown by elderly faces as opposed to young faces, although this effect was only observed for faces of the same sex. This effect was interpreted as resulting from the embodiment of the stereotypical slow movements associated with the elderly, leading to a decrease in arousal and consequently a slowing of the internal clock. Importantly, the effect was only observed for same-sex faces, suggesting that identification or motivation to empathize with the perceived individual may moderate embodiment processes.

This line of research highlights the deeply interconnected nature of our perceptual, emotional, and social cognitive processes. It demonstrates that something as seemingly objective as time perception can be influenced by complex social and emotional factors, mediated through embodied processes.

Moreover, these investigations highlight the significance of incorporating embodiment findings into cognitive research. The findings demonstrate that cognitive processes like time perception cannot be fully understood without taking into account the body's role in shaping our experiences and judgments. This embodied approach to cognition offers a richer, more comprehensive framework for understanding how we perceive and interact with the world around us.

In conclusion, the work of Effron et al. (2006) and Mondillon et al. (2007) provides compelling evidence for the embodied nature of emotional influences on time perception. These studies not only advance our understanding of time perception but also contribute to the broader field of embodied cognition, demonstrating how bodily states and actions play a crucial role in shaping our cognitive processes.

2.2.4 Neural Basis of Emotional Time Perception

Neuroimaging studies have begun to elucidate the complex neural mechanisms underlying emotional influences on time perception. These findings reveal intricate interactions between emotion-processing regions, attention networks, and core timing systems in the brain. The amygdala, a key structure in emotional processing, has been implicated in the temporal overestimation of emotional stimuli (Dirnberger, Hesselmann, Roiser, Preminger, & Jahanshahi, 2012). In their study, Dirnberger and colleagues found that participants perceived emotionally aversive stimuli as lasting longer than neutral stimuli presented for the same duration. This temporal distortion was associated with increased activation in the amygdala, suggesting its role in modulating time perception for emotional events.

The insula, another critical region involved in interoception and emotional awareness, has been associated with the integration of emotional and temporal information (Craig, 2009). Craig proposed a model of awareness based on interoceptive salience, which posits that the anterior insular cortex (AIC) contains a crucial neural component for the perception of time in humans. This model suggests that the AIC integrates emotional and physiological information to create a series of "global emotional moments" that form the basis of our subjective experience of time.

Further supporting the role of the insula in emotional time perception, Dirnberger et al. (2012) found that activity in the insula and putamen correlated with memory performance, but only during overestimation of time with aversive stimuli. This finding suggests that the insula may play a role in both the emotional modulation of time perception and the enhanced encoding of emotional events in memory.

The superior frontal gyrus has also been implicated in time perception with aversive stimuli (Dirnberger et al., 2012). Activation in this region during the presentation of emotionally aversive stimuli may reflect increased attentional resources allocated to processing these salient events, potentially contributing to the subjective expansion of time.

These neuroimaging findings align with behavioral observations of emotional influences on time perception. For instance, the subjective dilation of time during highly arousing or threatening situations (Droit-Volet & Meck, 2007) may be underpinned by increased activation in the amygdala and insula, leading to an overestimation of duration for emotional events.

The interaction between emotion and time perception likely involves a complex interplay between these emotion-processing regions and the core timing systems in the brain. The basal ganglia, particularly the putamen, have been implicated in timing processes (Coull et al., 2011). The observed correlation between putamen activation and memory performance during time overestimation of aversive stimuli (Dirnberger et al., 2012) suggests that emotional modulation of time perception may involve interactions between emotion-processing regions and these core timing structures.

Moreover, the anterior cingulate cortex (ACC), which is involved in cognitive control and emotional processing, has been shown to activate in conjunction with the insula during tasks involving both emotion and time perception (Craig, 2009). This co-activation suggests a potential role for the ACC in integrating emotional and temporal information, possibly contributing to the subjective experience of time in emotional contexts.

These findings collectively demonstrate that emotional influences on time perception involve complex interactions between multiple brain regions. The amygdala, insula, superior frontal gyrus, putamen, and ACC all play crucial roles in modulating our perception of time in emotional situations. This intricate neural network allows for the integration of emotional salience, attentional resources, and temporal processing, resulting in the subjective distortions of time often experienced during emotionally charged events.

2.3. Facial Trustworthiness

Facial trustworthiness is a rapidly processed and influential aspect of social cognition, with significant implications for social interactions and decision-making. Research in this area has focused on understanding how humans perceive and judge trustworthiness from facial features, the evolutionary basis of these judgments, and their neural underpinnings.

2.3.1 Evolutionary Perspectives on Trustworthiness Perception

The ability to quickly evaluate trustworthiness from faces is thought to have deep evolutionary roots. This capacity likely evolved as a crucial adaptation for survival in ancestral environments, where accurately assessing the intentions of others could mean the difference between life and death. Oosterhof and Todorov (2008) proposed an influential model suggesting that trustworthiness judgments are an extension of more basic mechanisms for detecting threat and interpreting emotional expressions.

Oosterhof and Todorov's (2008) research identified two fundamental dimensions underlying face evaluation: valence and dominance. The valence dimension, closely related to perceived trustworthiness, appears to be an overgeneralization of adaptive mechanisms for inferring harmful intentions. Their computer modeling demonstrated that faces judged as untrustworthy share visual properties with angry expressions, while trustworthy faces share properties with happy expressions. This finding supports the idea that trustworthiness judgments may have evolved from more primitive systems for detecting immediate threats or opportunities for cooperation.

The emotion overgeneralization hypothesis proposed by Zebrowitz and Montepare (2008) further elucidates the evolutionary basis of trustworthiness perception. This hypothesis suggests that facial features resembling emotional expressions (e.g., anger or happiness) influence not only momentary impressions but also more enduring trait inferences, including trustworthiness. For instance, individuals with subtle facial features resembling angry expressions may be perceived as less trustworthy, even when their face is emotionally neutral. This overgeneralization effect is thought to be adaptive, as it's less costly to mistakenly perceive an untrustworthy individual as trustworthy than to fail to detect an actual threat.

Zebrowitz and Montepare (2008) argue that these overgeneralization effects occur because the qualities revealed by facial cues that characterize emotions, along with other adaptive traits like maturity and fitness, tend to be perceived in people whose facial appearance merely resembles these qualities. This phenomenon helps explain why certain facial configurations are consistently judged as more or less trustworthy across different cultures, suggesting a universal basis for these judgments rooted in our evolutionary history.

The evolutionary importance of trustworthiness perception is further supported by research in evolutionary game theory. (McNamara, Stephens, Dall, & Houston, 2009) developed models demonstrating that social awareness and the ability to monitor cooperative tendencies can select for heritable polymorphisms in trustworthiness. Their work showed that allowing individuals to monitor each other's cooperative tendencies, even at a cost, can lead to the evolution of distinct personality types with varying levels of trustworthiness.

Importantly, McNamara et al.'s (2009) model revealed that the presence of individuals capable of social monitoring (at a cost) can maintain variation in trustworthiness within a population. This suggests that both the capacity to appear trustworthy and the ability to accurately detect trustworthiness in others have been shaped and maintained by evolutionary pressures. The model also helps explain the individual differences in trust and trustworthiness observed in experimental economic games across various cultures.

These evolutionary perspectives collectively suggest that our ability to rapidly evaluate trustworthiness from faces is not merely a byproduct of modern social complexities, but rather a deeply ingrained adaptive mechanism. The consistency of trustworthiness judgments across cultures, the rapid speed at which these judgments are made, and the neural systems involved in face evaluation all point to the evolutionary significance of this ability.

Understanding the evolutionary basis of trustworthiness perception not only provides insight into human social cognition but also has implications for various fields, including psychology, economics, and even artificial intelligence. As we continue to navigate complex social environments, these evolved mechanisms for assessing trustworthiness remain crucial, even if they are sometimes prone to biases or overgeneralization.

2.3.2 Facial Features Associated with Trustworthiness

Research has identified several facial features that consistently influence trustworthiness judgments. These features appear to serve as heuristic cues that people use to rapidly assess the potential intentions and capabilities of others.

Facial Width-to-Height Ratio (fWHR) has been shown to significantly impact perceptions of trustworthiness. Stirrat and Perrett (2010) found that faces with a higher width-to-height ratio are generally perceived as less trustworthy and more aggressive. This facial metric is calculated by dividing the bizygomatic width of the face by the height between the upper lip and mid-brow. Their research demonstrated that men with wider faces were more likely to exploit others' trust in economic games. Moreover, artificial manipulation of facial width in computer-generated faces influenced trustworthiness ratings. The effect was present for both male and female perceivers, but stronger for female participants. Interestingly, some studies have linked higher fWHR to actual aggressive behavior in men, suggesting a potential "kernel of truth" in these judgments. However, the authors note that the evolutionary basis for this relationship remains speculative.

Facial resemblance to emotional expressions also plays a crucial role in trustworthiness perceptions. (Said, Baron, & Todorov, 2009) demonstrated that even subtle facial features resembling emotional expressions can significantly impact trustworthiness judgments. Faces with features resembling happiness (e.g., slightly upturned mouth corners, higher cheekbones) are typically judged as more trustworthy, while faces with features resembling anger (e.g., lowered brow, tightened lips) are perceived as less trustworthy. Their neuroimaging results showed that the amygdala, a brain region involved in emotional processing, exhibited increased activation to both extremely trustworthy and untrustworthy faces, with a stronger response to untrustworthy faces. This suggests that trustworthiness judgments may be an overgeneralization of adaptive mechanisms for detecting emotional states signaling approach or avoidance behaviors.

Facial masculinity/femininity has also been found to influence trustworthiness perceptions. (Perrett, Lee, Penton-Voak, Rowland, & Yoshikawa et al., 1998) found that more feminine facial features are often associated with higher perceived trustworthiness. Their study showed that both male and female participants preferred feminized versions of faces when judging trustworthiness. This preference was observed across different cultures (British and Japanese participants) and was stronger for female faces but also present for male faces. The authors suggest this may be due to the association of feminine features with perceived warmth, youth, and approachability. However, they also note that this preference may limit sexual dimorphism in human faces.

Eye size and eyebrow height have been identified as important features in trustworthiness judgments. (Todorov, Baron, & Oosterhof, 2008) found that larger eyes and higher eyebrows tend to be associated with higher perceived trustworthiness. Their computer modeling of face trustworthiness showed that trustworthy faces tended to have larger eyes and higher inner eyebrows. These features may be perceived as trustworthy due to their resemblance to childlike features or positive emotional expressions. The authors suggest these cues might be overgeneralized from adaptive mechanisms for detecting vulnerability or friendly intent.

Skin texture has also been shown to influence trustworthiness perceptions. Tsankova and Kappas (2016) demonstrated that smoother skin texture is generally associated with higher perceived trustworthiness. Their study revealed that digitally smoothing skin blemishes increased ratings of trustworthiness, as well as competence, attractiveness, and health. This effect was present for both male and female faces, though slightly stronger for male faces. The authors suggest this may be due to the association of smooth skin with health, youth, and potentially higher socioeconomic status (ability to afford skincare).

It is crucial to note that these features interact in complex ways, and the overall configuration of the face, rather than individual features in isolation, determines trustworthiness judgments. Moreover, contextual factors, individual differences in perceivers, and cultural influences can all modulate the impact of these facial features on trustworthiness perceptions. The research in this area highlights the rapid and often unconscious nature of trustworthiness judgments based on facial appearance. While these judgments can influence important social outcomes, it is important to recognize that they may not accurately reflect a person's actual trustworthiness or character.

2.3.3 Neural Basis of Trustworthiness Perception

Expanding on the neural basis of trustworthiness perception, research has revealed a complex network of brain regions that contribute to this important social judgment process. The interplay between subcortical and cortical areas highlights the multifaceted nature of trustworthiness evaluations, involving both rapid, intuitive responses and more deliberative cognitive assessments.

The amygdala plays a crucial role in the automatic detection of potentially untrustworthy faces. (Engell, Haxby, & Todorov, 2007) demonstrated that amygdala activity increases in response to faces rated as untrustworthy, even when participants are not explicitly asked to evaluate trustworthiness. This finding suggests that the amygdala acts as an implicit "trustworthiness detector," rapidly flagging potentially threatening individuals. Interestingly, (Winston, Strange, O'Doherty, & Dolan, 2002) found that the amygdala response to untrustworthy faces was bilateral and persisted across both explicit and implicit trustworthiness judgment tasks, underscoring the robustness of this neural signature.

While the fusiform face area (FFA) is primarily associated with face recognition, Said, Haxby, & Todorov, 2011) provided evidence that this region also shows modulation based on perceived trustworthiness. This finding indicates that trustworthiness information is processed at relatively early stages of face perception, potentially influencing subsequent cognitive and emotional responses. The involvement of the FFA suggests that trustworthiness judgments may be intrinsically linked to the basic processes of face perception and recognition.

The insula's role in trustworthiness perception appears to be more complex. Winston et al. (2002) found that insula activation was associated with explicit trustworthiness judgments, potentially reflecting its involvement in integrating emotional and cognitive information. (Bzdok, Langner, Hoffstaedter, Turetsky, & Zilles, 2011) further elaborated on this, suggesting that the insula may be part of a network involved in the cognitive aspects of social judgments, including trustworthiness evaluations. The insula's activation during trustworthiness tasks may reflect interoceptive processes, as individuals consider their "gut feelings" about a face's trustworthiness.

The medial prefrontal cortex (mPFC) emerges as a key region for more deliberative aspects of trustworthiness judgments. Bzdok et al. (2011) identified the mPFC as part of a core social cognition network activated during trustworthiness and attractiveness judgments. This region may be involved in integrating facial trustworthiness information with other social knowledge and in making more reflective evaluations. The mPFC's role likely extends beyond simple face processing, encompassing higher-order social cognitive processes that contribute to trustworthiness decisions.

The involvement of these diverse brain regions underscores the complexity of trustworthiness perception. It appears to involve a rapid, automatic evaluation process mediated by subcortical structures like the amygdala, followed by more deliberative assessments involving cortical regions such as the mPFC and insula. This two-stage process allows for quick, intuitive responses to potentially untrustworthy individuals, while also enabling more nuanced judgments that can incorporate contextual information and social knowledge.

Furthermore, the neural basis of trustworthiness perception seems to be partially dissociable from other types of face evaluation. For example, while trustworthiness and attractiveness judgments share some neural substrates, they also show distinct patterns of activation in certain regions (Bzdok et al., 2011). This suggests that the brain may have specialized mechanisms for different types of social judgments, even when they are based on similar facial information.

It's worth noting that while these studies provide valuable insights into the neural correlates of trustworthiness judgments, they primarily rely on correlational data. Causal evidence from lesion studies or brain stimulation techniques would further strengthen our understanding of the specific roles of these brain regions in trustworthiness perception. This limitation highlights the need for future research to employ methods that can establish causal relationships between brain activity and trustworthiness judgments.

In conclusion, the neural basis of trustworthiness perception involves a distributed network of brain regions that contribute to both automatic and controlled aspects of this critical social judgment. While neuroimaging studies have provided significant insights into this process, future research using causal methods will be crucial for further elucidating how these different brain areas interact and how their relative contributions may vary depending on factors such as context, individual differences, and the specific nature of the trustworthiness evaluation task.

2.3.4 Cultural and Individual Differences in Trustworthiness Judgments

While there is considerable agreement in trustworthiness judgments across individuals and cultures, important differences have been observed:

Cultural Variations: Although the basic dimensions of face evaluation (including trustworthiness) appear to be relatively universal, the specific features associated with trustworthiness can vary across cultures. For example, (Sofer, Dotsch, Oikawa, Oikawa, & Wigboldus, 2017) found that Japanese and Israeli participants showed an "own-culture trustworthiness bias" - they rated faces more similar to their own culture's typical face as more trustworthy. This suggests that familiarity and in-group biases play a role in cross-cultural trustworthiness judgments.

Individual Differences: Factors such as personality traits, attachment styles, and personal experiences can influence an individual's trustworthiness judgments. (Dzhelyova, Perrett, & Jentzsch, 2012) found that individual differences in trustworthiness judgments were associated with differences in neural responses, particularly in the anterior insula. People who were more sensitive to facial trustworthiness cues showed greater anterior insula activation when viewing untrustworthy faces.

Gender Differences: Some studies have found that women tend to give higher trustworthiness ratings overall, particularly for trustworthy-looking faces. (Mattarozzi, Todorov, & Codispoti, 2014) observed that female participants rated faces as more trustworthy than male participants did, especially for faces that had been pre-rated as trustworthy. This gender difference was most pronounced for trustworthy female faces.

Age-Related Changes: Older adults often show a positivity bias in trustworthiness judgments, rating faces as more trustworthy overall compared to younger adults. (Castle, Eisenberger, Seeman, Moons, & Boggero et al., 2012) found that older adults (aged 55-84) rated untrustworthy faces as significantly more trustworthy and approachable than younger adults (aged 20-42) did. This age difference was specific to untrustworthy faces - older and younger adults did not differ in their ratings of trustworthy or neutral faces.

Clinical Populations: Individuals with conditions such as autism spectrum disorders or schizophrenia often show atypical patterns of trustworthiness judgments. (Adolphs, Sears, & Piven, 2001) found that individuals with autism may have difficulty discriminating between trustworthy and untrustworthy faces. In schizophrenia, (Hooker, Tully, Verosky, Fisher, & Holland et al., 2011) observed that patients may show heightened sensitivity to untrustworthy cues, especially when experiencing paranoid symptoms. These findings highlight how social cognitive processes involved in trustworthiness evaluations can be altered in certain clinical conditions.

Understanding these variations across cultures, individuals, and clinical populations is crucial for developing a comprehensive model of how humans perceive and judge trustworthiness. The differences observed demonstrate that while there are some universal tendencies, trustworthiness perception is also shaped by a variety of experiential, developmental, and neurobiological factors.

2.4. The Interplay between Facial Perception and Time Estimation

The intersection of facial perception and time estimation represents a fascinating area of research, bridging the fields of social cognition and time perception. While studies directly examining this relationship are relatively scarce, existing research provides intriguing insights into how these processes might interact.

2.4.1 Emotional Facial Expressions and Time Perception

Several studies have investigated how emotional facial expressions influence time perception, revealing a consistent pattern of temporal distortion effects:

Droit-Volet et al. (2004) conducted a seminal study using a temporal bisection task to examine how emotional facial expressions affect perceived duration. They found that angry faces were perceived as lasting longer than neutral faces of the same objective duration. This effect was attributed to increased arousal caused by threat-related stimuli, consistent with the internal clock model's prediction that higher arousal speeds up the pacemaker mechanism (Droit-Volet et al., 2004). The authors suggested this overestimation could reflect an adaptive mechanism, allowing more time for response preparation in threatening situations.

Tipples (2008) extended these findings by examining a broader range of emotional expressions. Using a similar temporal bisection paradigm, Tipples found that both angry and happy faces led to temporal overestimation compared to neutral faces. However, the effect was stronger for angry faces, suggesting a possible negativity bias in emotional time perception. Importantly, Tipples also demonstrated that individual differences in negative emotionality moderated this effect, with participants high in trait anxiety showing greater overestimation for angry faces (Tipples, 2008).

A study by Doi and Shinohara (2009) further explored the mechanisms underlying emotional influences on time perception. They demonstrated that the temporal distortion effect of emotional faces persists even when the faces are presented subliminally, indicating that conscious awareness of the emotion is not necessary for it to influence time perception. This finding suggests that the effect occurs at an early, automatic stage of processing (Doi & Shinohara, 2009).

Additionally, Doi and Shinohara (2009) examined how gaze direction interacts with emotional expression to influence perceived duration. They found that angry faces with direct gaze were perceived as lasting longer than angry faces with averted gaze. This interaction between emotion and gaze was not observed for happy faces, highlighting the particular salience of threat-related signals directed at the observer (Doi & Shinohara, 2009).

These studies collectively highlight the robust influence of facial emotions on time perception, likely mediated by changes in arousal and attention. The findings are consistent with evolutionary accounts suggesting enhanced processing of emotionally salient stimuli, particularly those related to potential threats. Moreover, the research underscores the intricate relationship between emotion, attention, and time perception, demonstrating how our subjective experience of time is shaped by the affective significance of events.

2.4.2 Dynamic Facial Expressions and Temporal Judgments

Research on dynamic facial expressions provides further insights into the facial perception-time estimation relationship:

Fayolle and Droit-Volet (2014) conducted a seminal study in this area, employing a temporal bisection task to compare time judgments for static and dynamic emotional facial expressions. Their results revealed that dynamic displays of emotions led to more pronounced temporal distortions than static images, with a particular emphasis on expressions transitioning from neutral to emotional states. This finding suggests that the perception of emotional change itself may be a critical factor in modulating time perception, rather than merely the final emotional state displayed (Fayolle & Droit-Volet, 2014).

The work of (Lambrechts, Mella, Pouthas, & Noulhiane, 2011) further corroborated the unique influence of facial dynamics on time perception. Their study demonstrated that the duration of dynamic facial expressions was consistently overestimated compared to non-facial dynamic stimuli. This overestimation effect points to a specialized processing mechanism for facial motion, potentially rooted in the high social relevance of facial expressions in human interaction (Lambrechts et al., 2011). The authors proposed that this effect might be due to increased attentional resources allocated to facial movements, which are rich in social and emotional information.

To explain these findings, Gil and Droit-Volet (2009) proposed that the temporal distortions observed in response to dynamic facial expressions could be attributed to embodied simulation processes. According to this perspective, observers internally simulate the perceived facial movements, leading to activation of emotion-related neural circuits and consequent modulation of internal timing mechanisms. This embodied approach provides a potential explanatory framework for the enhanced temporal effects observed with dynamic facial expressions compared to static ones. Including this theoretical explanation in the literature review is appropriate as it offers a deeper understanding of the underlying mechanisms that may drive the observed effects of dynamic facial expressions on time perception.

(Krumhuber, Kappas, & Manstead, 2013) conducted a comprehensive review of the effects of dynamic aspects of facial expressions on emotion perception. They noted that dynamic displays generally lead to more accurate emotion recognition and heightened judgments of emotion intensity compared to static images. This enhanced processing of dynamic facial expressions may contribute to their more pronounced effects on time perception, as observed in the studies by Fayolle and Droit-Volet (2014) and Lambrechts et al. (2011).

It is also important to consider individual differences in the relationship between dynamic facial expressions and time perception. Tipples (2008) found that individuals high in trait anxiety showed greater temporal overestimation for angry facial expressions, suggesting that personal characteristics can modulate the impact of emotional facial dynamics on time judgments. This finding highlights the importance of considering individual variability when examining the relationship between facial expression dynamics and temporal perception. Incorporating this information into the main text provides a more nuanced understanding of the topic and emphasizes that the effects of dynamic facial expressions on time perception are not uniform across all individuals, pointing to potential areas for future research.

In summary, the existing literature on dynamic facial expressions and temporal judgments points to a complex interplay between emotion perception, attentional processes, and time estimation. The enhanced temporal distortions observed for dynamic facial expressions underscore the importance of considering the temporal unfolding of emotional displays in understanding how social stimuli influence our perception of time. Future research in this area may benefit from exploring the neural mechanisms underlying these effects and investigating how they manifest in more ecologically valid social contexts.

2.4.3 Facial Trustworthiness and Time Perception

While direct studies on the influence of facial trustworthiness on time perception are limited, related research provides some clues about potential relationships and mechanisms.

Okubo and Ishikawa (2011) examined how emotional valence and brightness influence time perception using a visual half-field paradigm. They found that faces rated as more likeable were perceived as being presented for longer durations. Specifically, positive words were recognized better when presented in white fonts compared to black fonts, while the opposite effect occurred for negative words. This emotional valence effect interacted with the visual field, occurring only for stimuli presented to the right visual field/left hemisphere. Given the close relationship between likeability and trustworthiness judgments (Oosterhof & Todorov, 2008), these findings suggest that more trustworthy faces might also be perceived as lasting longer. The hemispheric asymmetry observed also points to the potential involvement of emotion-related neural circuits in mediating these effects.

Ogden (2013) demonstrated that social exclusion leads to overestimation of time intervals. In this study, participants completed a temporal bisection task judging the duration of attractive, unattractive and neutral faces. Results showed that unattractive faces were judged as shorter in duration compared to attractive and neutral faces. The author interpreted this as an attentional effect, with unattractive faces capturing attention away from timing processes. Considering that untrustworthy faces might evoke feelings of social threat or exclusion similar to unattractive faces, this could imply that untrustworthy faces might lead to an overestimation of time intervals through attentional capture mechanisms.

A study by Tomas and Španić (2016) directly investigated the interaction between facial attractiveness and time perception. Using a temporal bisection task, they found that attractive faces were judged to be presented for longer durations compared to unattractive faces. This effect was more pronounced for angry expressions, suggesting an interaction between attractiveness and emotional expression in influencing time perception. Given that facial attractiveness is generally correlated with perceived trustworthiness (Todorov et al., 2008), these findings hint at potential similar effects for trustworthy versus untrustworthy faces. The interaction with emotional expression is particularly noteworthy, as it suggests that trustworthiness judgments may modulate the impact of emotion on time perception.

Research by Gil and Droit-Volet (2011) on the effect of emotional facial expressions on time perception showed that the temporal overestimation of angry faces was more pronounced for longer durations. They tested five different temporal tasks: bisection, generalization, verbal estimation, production and reproduction. Results showed an overestimation of time for angry compared to neutral faces in the temporal bisection, verbal estimation and production tasks, but not in the temporal generalization and reproduction tasks. If trustworthiness judgments interact with emotional processing in a similar manner, we might expect a comparable pattern for trustworthy versus untrustworthy faces, particularly when combined with emotional expressions. The task-dependence of the effects also highlights the importance of considering multiple timing paradigms when investigating these phenomena.

Mondillon et al. (2007) found that the effect of angry facial expressions on time perception was modulated by the ethnicity of the face, with participants showing greater temporal distortions for in-group faces. Specifically, Caucasian participants overestimated the duration of angry

Caucasian faces but not angry Chinese faces. Given that in-group faces are often perceived as more trustworthy (Farmer et al., 2014), this suggests a potential interaction between perceived trustworthiness and emotional expression in influencing time perception. The authors interpreted these findings in terms of embodied simulation processes, proposing that participants more readily simulate the emotional states of in-group members.

These findings, while not directly addressing facial trustworthiness, suggest several potential mechanisms through which trustworthiness might influence time perception:

a) Arousal: If trustworthy faces are perceived as more positive and less threatening, they might induce lower levels of arousal compared to untrustworthy faces. According to the internal clock model (Treisman, 1963; Gibbon et al., 1984), this could lead to shorter perceived durations for trustworthy faces due to a slower pacemaker rate.

b) Attention: Untrustworthy faces might capture more attention due to their potential threat value. This increased attention allocation could lead to longer perceived durations for untrustworthy faces, in line with attentional models of time perception (Zakay et al., 2004). However, if untrustworthy faces divert attention away from timing processes, this could alternatively lead to shorter perceived durations.

c) Embodied simulation: If perceivers engage in more embodied simulation when viewing trustworthy faces (due to greater social affiliation), this could lead to changes in physiological states that influence time perception. This is consistent with embodied cognition approaches to timing (Effron et al., 2006; Wittmann, 2013).

d) Cognitive load: Processing untrustworthy faces might impose a higher cognitive load, potentially interfering with timing processes and leading to distortions in time perception. This aligns with cognitive models of timing that emphasize the role of working memory and executive functions (Buhusi & Meck, 2005).

However, it's important to note that these potential effects are speculative and require direct empirical investigation. The complex interplay between facial trustworthiness, emotional expression, and time perception remains an open area for research. Future studies should systematically manipulate facial trustworthiness while controlling for related variables like attractiveness and emotion. Additionally, employing multiple timing paradigms and investigating potential moderators (e.g., individual differences in trust propensity) would help elucidate the mechanisms underlying any observed effects.

2.4.4 Methodological Considerations

When studying the relationship between facial trustworthiness and time perception, several methodological considerations are important to ensure robust and interpretable results. The selection of appropriate timing tasks is crucial, as different tasks (e.g., duration bisection, temporal reproduction, verbal estimation) may yield varying results due to their distinct cognitive demands. Gil and Droit-Volet (2011) demonstrated that the effect of emotional expressions on time perception varied depending on the specific timing task used, observing an overestimation of time for angry compared to neutral faces in temporal bisection, verbal estimation, and production tasks, but not in temporal generalization and reproduction tasks. This task-dependent effect underscores the importance of employing multiple timing paradigms to gain a comprehensive understanding of how facial trustworthiness influences time perception. The choice of task should be guided by specific research questions and hypotheses, considering that temporal bisection tasks are useful for examining categorical time judgments and are sensitive to arousal effects (Droit-Volet et al., 2004), reproduction tasks may be more sensitive to attentional effects and working memory processes (Baudouin, Vanneste, Isingrini, & Pouthas, 2006), and verbal estimation tasks provide direct quantitative estimates but may be influenced by numerical biases (Wearden, 2015).

The duration range of stimuli presentation is another critical factor, as the effects of facial trustworthiness on time perception may vary for different time intervals. Short durations (e.g., <1 second) might be more influenced by automatic, arousal-based mechanisms, while longer durations might involve more cognitive, attention-based processes (Lewis & Miall, 2003). Angrilli et al. (1997) found that the effect of emotional valence on time perception reversed for short (2-4s) versus long (4-6s) durations, highlighting the importance of testing multiple duration ranges to capture potential differences in underlying mechanisms. The choice of duration range should also consider the typical timescales involved in trustworthiness judgments from faces, which can occur rapidly (within 100ms; Willis & Todorov, 2006).

Stimulus complexity is another important consideration, as the use of static versus dynamic facial stimuli could yield different results. Dynamic stimuli provide more ecological validity but also introduce additional temporal information. Fayolle and Droit-Volet (2014) found that dynamic displays of emotional expressions led to greater temporal distortions than static displays. For trustworthiness research, dynamic stimuli might better capture the subtle cues that contribute to trustworthiness judgments, such as micro-expressions and gaze patterns. Researchers should consider using both static and dynamic stimuli to compare effects, controlling for low-level visual features (e.g., contrast, luminance) that might influence time perception, and employing computer-generated faces to precisely manipulate trustworthiness-related features (Todorov, Dotsch, Porter, Oosterhof, & Falvello, 2013).

Individual differences play a significant role in moderating the relationship between facial trustworthiness and time perception. Factors such as anxiety levels, cultural background, and social cognitive abilities may influence this relationship. Tipples (2008) found that trait anxiety moderated the effect of angry faces on time perception. Cultural display rules and in-group/out-group effects might influence trustworthiness judgments and their impact on timing (Elfenbein & Ambady, 2002). Moreover, individual differences in social cognitive abilities, such as theory of mind or empathy, might affect the degree to which participants engage in embodied simulation of perceived faces (Mondillon et al., 2007). Researchers should consider measuring relevant individual difference variables and including them as moderators in analyses, while also employing diverse participant samples to assess the generalizability of findings across cultures and demographic groups.

The distinction between implicit and explicit trustworthiness judgments is another crucial methodological consideration. Whether participants are explicitly asked to judge trustworthiness or if trustworthiness is implicitly varied could influence the observed effects on time perception. Explicit judgments might draw attention to trustworthiness-related features, potentially amplifying their effects on timing, while implicit manipulations might capture more automatic, unconscious influences of perceived trustworthiness. Researchers could benefit from comparing explicit and implicit trustworthiness manipulations within the same study, using priming techniques to activate trustworthiness-related concepts without explicit judgments, and employing indirect measures of trustworthiness (e.g., approach/avoidance tendencies) alongside timing tasks.

To isolate the specific effects of facial trustworthiness, it's important to include appropriate control conditions and comparisons. This might involve comparing trustworthy/untrustworthy faces to neutral faces, including non-face control stimuli to assess whether effects are face-specific, and manipulating other facial dimensions (e.g., attractiveness, dominance) to disentangle their effects from trustworthiness.

Given the potentially subtle effects of facial trustworthiness on time perception, careful statistical considerations are necessary. Researchers should conduct a priori power analyses to ensure adequate sample sizes, consider using Bayesian analyses to quantify evidence for both the presence and absence of effects, and employ robust statistical techniques to handle potential outliers and non-normal distributions often encountered in timing data.

Finally, to build a cumulative understanding of the relationship between facial trustworthiness and time perception, researchers should prioritize replication and open science practices. This includes conducting direct replications of key findings, engaging in open science practices such as pre-registration and data sharing, and collaborating on large-scale, multi-lab studies to establish the reliability and generalizability of effects.

By carefully considering these methodological factors, future research investigating the relationship between facial trustworthiness and time perception can provide a more comprehensive and nuanced understanding of this complex interaction. This will not only advance our theoretical knowledge but also potentially inform practical applications in fields such as social decision-making, criminal justice, and human-computer interaction.

2.5. Conclusion and Future Directions

The interplay between facial perception, particularly trustworthiness judgments, and time perception represents a rich area for future research. While existing studies have provided valuable insights into how emotional facial expressions influence time perception, the specific role of perceived trustworthiness remains largely unexplored.

This literature review has explored the complex interplay between facial perception, particularly trustworthiness, and time perception. We have examined the foundational theories of time perception, including internal clock models, cognitive models, and neuroscientific perspectives. These theories provide a framework for understanding how various factors, including emotional and social cues, can influence our subjective experience of time.

The review has highlighted the significant impact of emotions on time perception, with a particular focus on how facial expressions can alter temporal judgments. The arousal and attention mechanisms proposed to underlie these effects offer potential explanations for how facial trustworthiness might influence time perception.

We have also delved into the concept of facial trustworthiness, exploring its evolutionary basis, the facial features associated with trustworthiness judgments, and the neural underpinnings of trustworthiness perception. This background provides a foundation for understanding how trustworthiness might interact with temporal processing.

While direct research on the relationship between facial trustworthiness and time perception is limited, the existing literature on related topics suggests several potential mechanisms through which trustworthiness could influence temporal judgments. These include arousal-based effects, attentional capture, embodied simulation, and cognitive load.

The review has also highlighted important methodological considerations for future research in this area, including the choice of timing tasks, duration ranges, and stimulus types. Individual differences and cultural factors have been noted as important moderators to consider in future studies.

Moving forward, there is a clear need for direct empirical investigation of how facial trustworthiness influences time perception. Such research could provide valuable insights into the broader question of how social cognitive processes interact with our perception of time. This line of inquiry has potential implications not only for our basic understanding of cognitive and perceptual processes but also for applied fields such as social psychology, decision-making, and even clinical interventions for disorders involving social cognitive or temporal processing deficits.

In conclusion, the intersection of facial trustworthiness and time perception represents a promising and largely unexplored area of research. By building on the solid foundation of existing work in both facial perception and time perception, future studies in this area have the potential to significantly advance our understanding of how we perceive and interact with the social world around us.

Future studies could focus on:

1. Directly manipulating facial trustworthiness and measuring its effects on various time perception tasks.

2. Investigating how trustworthiness interacts with emotional expressions to influence time perception.

3. Exploring the neural mechanisms underlying the potential influence of facial trustworthiness on time perception.

4. Examining how individual differences in social cognition and personality traits moderate the relationship between facial trustworthiness and time perception.

5. Investigating potential clinical implications, such as how atypical trustworthiness perception in certain disorders (e.g., social anxiety, autism spectrum disorders) might relate to temporal processing biases.

By pursuing these research directions, we can gain a more comprehensive understanding of how social cognitive processes, including trustworthiness judgments, interact with our perception of time. This knowledge could have important implications for understanding social interactions, decision-making processes, and potentially even clinical interventions for disorders involving social cognitive or temporal processing deficits.

3. Methodology

3.1 Participants

A total of 82 participants were recruited for this study. The sample size was determined a priori using G*Power 3.1 (Faul et al., 2007), assuming a medium effect size ($f = 0.25$), $\alpha = 0.05$, and power ($1 - \beta$) = 0.80 for a repeated measures ANOVA.

3.1.1 Demographic Characteristics

The participant pool exhibited a diverse range of demographic characteristics. The mean age of the participants was 24.72 years (SD = 4.99), with ages ranging from 18 to 44 years. The gender distribution of the sample was predominantly female, with 55 participants (67.1%) identifying as female, 24 (29.3%) as male, and 1 (1.2%) as other. Two participants (2.4%) did not specify their gender.

Regarding handedness, the majority of participants (66, 80.5%) reported being right-handed. Eight participants (9.8%) were left-handed, and four (4.9%) identified as ambidextrous. Four participants (4.9%) did not specify their handedness.

The sample was notably diverse in terms of nationality, with participants from at least 20 different countries. The most represented nationalities were Serbian (24 participants, 29.3%), Italian (11 participants, 13.4%), Turkish (8 participants, 9.8%), Iranian (6 participants, 7.3%), and American (5 participants, 6.1%). Other nationalities, including Indian, Pakistani, Lebanese, Greek, and Dutch, were also represented, each accounting for less than 5% of the sample.

The linguistic diversity of the sample was equally noteworthy, with participants reporting 19 different first languages. Serbian was the most common first language, spoken by 24 participants (29.3%), followed by Italian (10 participants, 12.2%), Turkish (8 participants, 9.8%), English (7 participants, 8.5%), and Persian (6 participants, 7.3%). Other languages represented in the sample included Arabic, Russian, German, and Greek, each spoken by less than 5% of the participants.

This diverse sample provides a rich dataset for examining potential cultural and linguistic influences on time perception and facial trustworthiness judgments. The international nature of the participant pool enhances the generalizability of the study findings across different cultural contexts.

3.1.1 Sampling Procedure

Participants were recruited via email from the university student population. The diverse nature of the sample suggests an international recruitment strategy, possibly leveraging online platforms to reach participants from various countries. Each participant was assigned a unique subject code to ensure anonymity during data collection and analysis.

3.1.2 Inclusion and Exclusion Criteria

Inclusion criteria were: (a) age 18 years or older, (b) normal or corrected-to-normal vision, and (c) fluency in the language of instruction. Exclusion criteria included a history of neurological or psychiatric disorders that could affect time perception.

3.1.4 Ethical Considerations

All participants provided informed consent before participating in the study. The study protocol was approved by University of Pavia. Participant data were anonymized, with each participant assigned a unique identifier to protect their privacy.
This diverse sample provides a rich dataset for examining potential cultural and linguistic influences on time perception and facial trustworthiness judgments. The international nature of the participant pool enhances the generalizability of the study findings across different cultural contexts.

3.2 Materials and Apparatus

3.2.1 Experimental Software: PsychoPy

The experiment was programmed and executed using PsychoPy v2023.1.0 (Peirce et al., 2019), a Python-based software for designing psychology experiments. PsychoPy was chosen for several key features that made it particularly suitable for our study.
PsychoPy offers versatile experiment creation capabilities through both a graphical user interface (Builder) and a scripting interface (Coder), allowing for flexible experiment design. In this study, we utilized the graphical user interface to achieve precise control over stimulus presentation and timing. This versatility was complemented by PsychoPy's precise temporal and spatial control features. The software provides high-precision control over the temporal aspects of stimulus presentation, which was crucial for our time perception task. Its ability to accurately time stimulus durations and record response times with millisecond precision was essential for our experimental design.

While our study focused primarily on visual stimuli, specifically facial images, PsychoPy's capability to handle a wide range of stimuli types, including visual and auditory, ensures flexibility for potential future extensions of this research. This broad support for various stimuli types makes PsychoPy a versatile tool for diverse psychological experiments.

The online experiment capability of PsychoPy was another crucial feature for our study. Its support for online experiment deployment via PsychoJS allowed us to conduct our study remotely, enabling broader participant recruitment. This feature was particularly valuable given the diverse, international nature of our participant pool.

Data collection and export were streamlined through PsychoPy's built-in features. These facilitated efficient recording of participant responses and reaction times, simplifying the data analysis process. The software's comprehensive data management capabilities ensured that all relevant experimental data were captured accurately and could be easily exported for further analysis.

Finally, PsychoPy's open-source nature aligns well with principles of open science, enhancing the reproducibility of our experimental paradigm. This aspect of PsychoPy contributes to the transparency and replicability of our research, which are crucial considerations in contemporary psychological science.

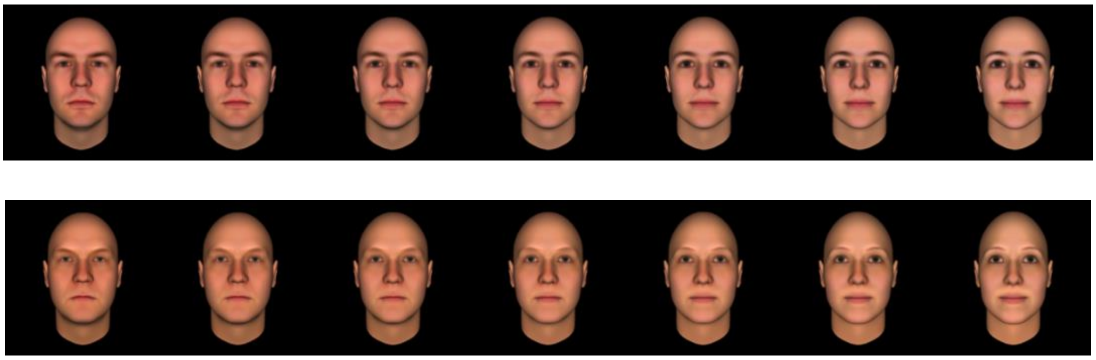
In sum, PsychoPy's combination of versatile design options, precise control, online capabilities, efficient data management, and commitment to open science principles made it an ideal choice for implementing our experimental paradigm on facial trustworthiness and time perception.

3.2.2 Stimuli

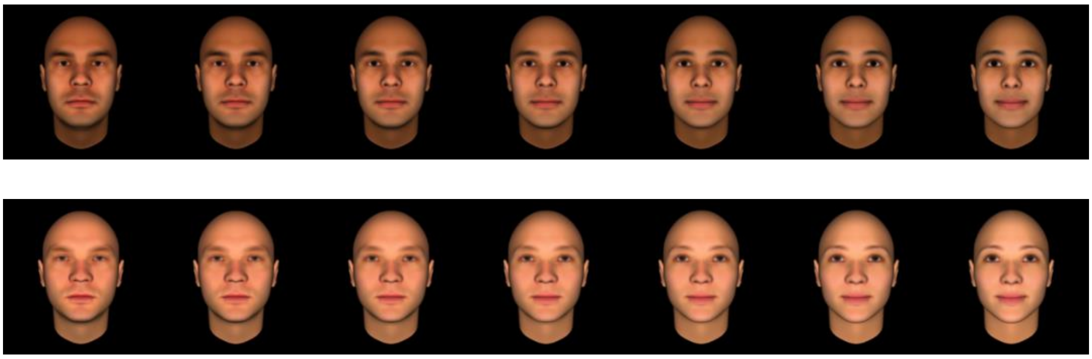
Facial stimuli were sourced from the computer-generated face database developed by Oosterhof and Todorov (2008) in their seminal work on the functional basis of face evaluation. This database was specifically designed to systematically manipulate facial features associated with perceived trustworthiness. The stimuli were organized as follows:

The stimulus structure was carefully designed to allow for systematic manipulation of facial trustworthiness while controlling for individual facial features. Four distinct groups of faces were used, with two groups presented in each experimental block. Each group consisted of one unique facial identity presented at seven levels of trustworthiness. For each facial identity, seven versions were created, ranging from -3 (extremely untrustworthy) to +3 (extremely trustworthy) in increments of 1. This resulted in a total of 28 unique stimuli (4 identities × 7 trustworthiness levels).

The stimuli were distributed across two experimental blocks. Block 1 contained two groups of faces, comprising 14 stimuli (2 identities × 7 trustworthiness levels). Block 2 contained the other two groups of faces, also comprising 14 stimuli (2 identities × 7 trustworthiness levels). In each block, the 14 unique stimuli were presented multiple times at various durations, resulting in 98 trials per block.



Block 1 (Including categories 1 and 2)



Block 2 (Including categories 4 and 5)

To ensure consistency and control for potential confounds, all images were standardized. The stimuli were presented on a black background to ensure consistent contrast across different participant displays.

This carefully structured stimulus set allowed for the systematic manipulation of facial trustworthiness while controlling for individual facial features. This design ensured that any observed effects on time perception could be attributed to changes in perceived trustworthiness rather than to idiosyncratic facial characteristics.

3.2.3 Apparatus

The experiment was conducted online, with participants using their personal computers. To maintain consistency in stimulus presentation, several measures were implemented.

Participants were required to use the Google Chrome browser, ensuring compatibility with PsychoPy running on the Pavlovia platform. A brief display calibration procedure was implemented at the beginning of the experiment to adjust for variations in participants' screen sizes and resolutions. Standard keyboard input was used for responses, with specific keys ('A', 'K', and space bar) designated for different response types. A stable internet connection was required to ensure smooth running of the experiment and accurate timing of stimulus presentations.

3.3 Experimental Design

The study employed a two-part experimental design: a temporal bisection task followed by a manipulation check.

3.3.1 Temporal Bisection Task

This study employed a temporal bisection task, a widely used paradigm in time perception research (Allan & Gibbon, 1991; Wearden, 1991). The temporal bisection task is particularly useful for investigating subjective time perception and has been successfully applied in various contexts, including the study of emotional influences on time perception (Droit-Volet et al., 2004).

The task in this study featured several key elements. Participants were initially exposed to two anchor durations: a "short" standard (e.g., 2000 ms) and a "long" standard (e.g., 5000 ms), which established the temporal framework for subsequent judgments. A training phase followed, where participants practiced categorizing durations as either "short" or "long" based on the anchor durations, ensuring they could distinguish between the two standard durations.

In the test phase, participants were presented with facial stimuli for various durations, including and between the anchor durations. For each presentation, participants judged whether the duration was closer to the "short" or "long" standard. The primary dependent variable was the proportion of "long" responses for each stimulus duration and facial trustworthiness level. This allows for the calculation of the point of subjective equality (PSE) and the Weber ratio, key measures in temporal bisection tasks.

Psychometric functions were fitted to the data to derive measures of temporal sensitivity and bias as part of the psychophysical analysis. The temporal bisection task was chosen for this study because it provides a sensitive measure of subjective time perception, allows for the investigation of how non-temporal factors (in this case, facial trustworthiness) can influence time judgments, and is relatively simple for participants to understand and perform, making it suitable for online administration.

3.3.2 Manipulation Check

Following the main temporal bisection task, a manipulation check was conducted to validate the perceived trustworthiness of the facial stimuli. The purpose of this check was to assess whether participants' explicit judgments of facial trustworthiness aligned with the intended manipulation levels and to provide a basis for comparing implicit effects (from the temporal bisection task) with explicit judgments.

In the procedure, participants were presented with the same facial stimuli used in the main experiment. For each face, participants rated the perceived trustworthiness on a 9-point Likert scale (1 = extremely untrustworthy, 9 = extremely trustworthy). All 28 unique facial stimuli were presented (4 identities × 7 trustworthiness levels), with the order of presentation randomized for each participant. Participants used the numerical keys (1-9) on their keyboard to input their ratings. Both trustworthiness ratings and response times were recorded for each stimulus.

This manipulation check serves as a critical component of the study design, allowing for verification of the effectiveness of the trustworthiness manipulation, exploration of potential discrepancies between implicit (time perception) and explicit (trustworthiness rating) judgments, and assessment of individual differences in trustworthiness perception.

3.3.3 Variables

The study included two main categories of variables: independent and dependent. The independent variables were facial trustworthiness, with 7 levels ranging from -3 to +3, and stimulus duration, also with 7 levels (specific durations to be specified, e.g., 2000, 2500, 3000, 3500, 4000, 4500, 5000 ms).

The dependent variables were divided between the Temporal Bisection Task and the Manipulation Check. For the Temporal Bisection Task, the dependent variables included the binary response of perceived duration (short/long) and the reaction time for each judgment. For the Manipulation Check, the dependent variable was the explicit trustworthiness ratings on a 1-9 scale.

3.4 Procedure

The experiment was conducted online using PsychoPy (version 2022.2.4) and consisted of several phases:

3.4.1 Participant Registration and Demographics

Upon accessing the experiment link, participants were presented with a digital form to input their unique subject code, age, sex, dominant hand, nationality, and first language.

3.4.2 Instructions and Training

Participants were provided with on-screen instructions detailing the task requirements. They were shown examples of faces presented for short (2 seconds) and long (5 seconds) durations. Response instructions were given: press "A" with left index finger for short duration, press "K" with right index finger for long duration, press space bar to initiate each trial, and respond within 5 seconds after the question mark appears.

3.4.3 Practice Phase

A practice session consisting of 8 trials was conducted. In this phase, participants received immediate feedback (correct/incorrect) on their responses. Practice stimuli were presented for either 2, 2.5, 4.5, or 5 seconds. This phase ensured participants understood the task requirements before proceeding to the main experiment.

3.4.4 Main Experimental Blocks

The main experiment consisted of two blocks, each containing 98 trials. Participants were informed that this phase would be similar to the practice but longer and without feedback. In each trial, the word "Ready" appeared on screen, participants pressed the space bar to initiate the trial, a face was presented for a variable duration (2, 2.5, 3, 3.5, 4, 4.5, or 5 seconds), a question mark appeared prompting a response, and participants had 5 seconds to categorize the duration as "short" or "long". A two-minute rest period was provided between the two blocks.

3.4.5 Trustworthiness Rating Task (Manipulation Check)

Following the main experimental blocks, participants completed a trustworthiness rating task. The same faces from the main experiment were presented, and participants rated each face on a 1-9 scale of trustworthiness (1 = extremely untrustworthy, 9 = extremely trustworthy). Responses were made by pressing the corresponding numerical key on the keyboard. A total of 28 faces were rated (7 trustworthiness levels for each of the 4 identities used in the main experiment).

3.5 Data Acquisition and Preprocessing

Data were collected using PsychoPy (version 2022.2.4) and exported as CSV files. The initial raw data file, "subjdata_e1a_objAcross.csv", contained trial-level information for each participant, including response times (RTs) and accuracy for each trial.

Data preprocessing was conducted using R (version 4.1.0; R Core Team, 2021) with the tidyverse package suite (Wickham et al., 2019). The preprocessing pipeline consisted of several steps:

1. Initial Data Processing: The raw data were first processed to calculate mean vision reaction times (RTs) for congruent and incongruent trials for each participant. This was done using the dplyr and tidyr packages. The processed data were then merged back with the original dataset to create a comprehensive dataset containing both trial-level and participant-level summary statistics.
2. Outlier Removal: Outliers were identified and removed using a standard deviation approach. For each participant, trials with RTs more than 3 standard deviations away from their mean RT were flagged as outliers and excluded from further analysis.
3. Accuracy Filtering: Only correct trials (trialaccuracy == 1) were retained for the main analyses to ensure that the RT data reflected accurate performance.
4. Data Reshaping: The data were reshaped into both wide and long formats to facilitate different types of analyses. In the wide format, each row represented a participant with separate columns for congruent and incongruent RTs. In the long format, each row represented a condition (congruent or incongruent) for each participant.
5. Signal Detection Analysis: To account for potential speed-accuracy trade-offs, we calculated d-prime scores for each participant in both congruent and incongruent conditions. D-prime is a measure from signal detection theory that provides a bias-free measure of sensitivity. The calculation included a correction for extreme values (hits or false alarms of 0 or 1) using the log-linear rule (Hautus, 1995).
6. Final Dataset Creation: The final preprocessed datasets included participant-level summary statistics (mean RTs and d-prime scores for congruent and incongruent conditions) in both wide and long formats. These datasets were saved as

"exp1a_wide_for_jasp_corrected.csv" and "exp1a_long_for_jasp_corrected.csv" respectively.

In addition to the primary data preprocessing steps, we conducted further data cleaning and preparation specifically for the trustworthiness ratings:

1. Data Import: Trustworthiness ratings data were imported from an Excel file ("Long_Ratings.xlsx") using the openxlsx package in R.
2. Experimenter Data Removal: Data entries from the experimenters (identified as "JOVANA MUNJIC" and "Reyhaneh Borjian") were removed from the dataset to ensure only participant data were included in the analysis.
3. Exclusion Based on Response Accuracy: Participants with more than 50% inaccurate responses (15 or more out of 28 trials) in the shortest (2s) or longest (5s) intervals were excluded from further analysis. This resulted in the removal of data from participants S49, S92, and S48. This step was taken to ensure data quality and reliability.
4. Preparation for Linear Mixed Models: The 'Participant' and 'identity' variables were converted to factors to prepare for linear mixed models (LMM) analysis. This allows for the inclusion of these variables as random intercepts in subsequent statistical models, accounting for individual differences among participants and potential variations among face identities.

This preprocessing pipeline ensured that the data were cleaned, organized, and appropriately formatted for subsequent statistical analyses, including both frequentist and Bayesian approaches.

4. Result

4.1 Temporal Bisection Task

4.1.1 Effect of Facial Trustworthiness on Time Perception

We investigated the effect of facial trustworthiness on time perception using a temporal bisection task. Our analysis employed a Generalized Linear Mixed Effects Model (GLMM) to account for the binary nature of the response variable (short/long) and the nested structure of our data.

Model Specification

We fitted a GLMM that included fixed effects for trustworthiness level (as a continuous variable) and stimulus duration, as well as random intercepts for participants and facial identities.

Main Effects

The analysis revealed significant main effects for both trustworthiness level and stimulus duration:

1. **Trustworthiness Level: $\chi^2(1) = 5.9491$, $p = 0.01472$**
2. **Stimulus Duration: $\chi^2(6) = 4402.3897$, $p < 2e-16$**

The effect of trustworthiness was small but significant, with an estimate of -0.02882 (SE = 0.01182, z = -2.439, p = 0.0147). This negative coefficient indicates that as trustworthiness increased, the probability of a "long" response decreased slightly.

The effect of stimulus duration was much stronger, with all duration levels showing highly significant differences from the baseline (all $p < 2e-16$).

To further elucidate the complex relationship between facial trustworthiness and time perception, we examined the interaction between trustworthiness levels and stimulus durations. This analysis aimed to determine whether the effect of facial trustworthiness on time judgments varies across different presentation durations.

The analysis revealed:

1. A marginally significant interaction between trustworthiness level and stimulus duration ($\chi^2(6) = 12.5071$, $p = 0.05157$).
2. The interaction model provided a slightly better fit to the data compared to the main effects model ($\chi^2 = 12.592$, $df = 6$, $p = 0.04998$).

Visualization and Interpretation of the Interaction

The interaction effect is visualized in Figure 2, which illustrates the predicted probability of "long" responses across different durations for various trustworthiness levels.

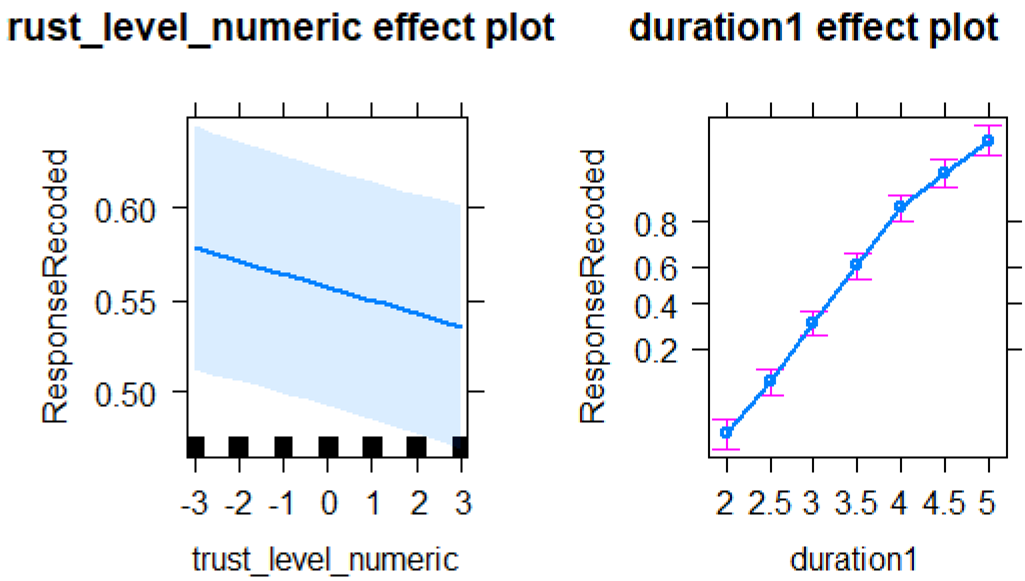


FIGURE 1: Effects plot

Figure 1 illustrates the main effects of trustworthiness level and stimulus duration on the probability of "long" responses. The trust_level effect plot shows a subtle, linear decrease in the probability of a "long" response as trustworthiness increases. The duration1 effect plot demonstrates a strong, positive relationship between stimulus duration and the probability of a "long" response.

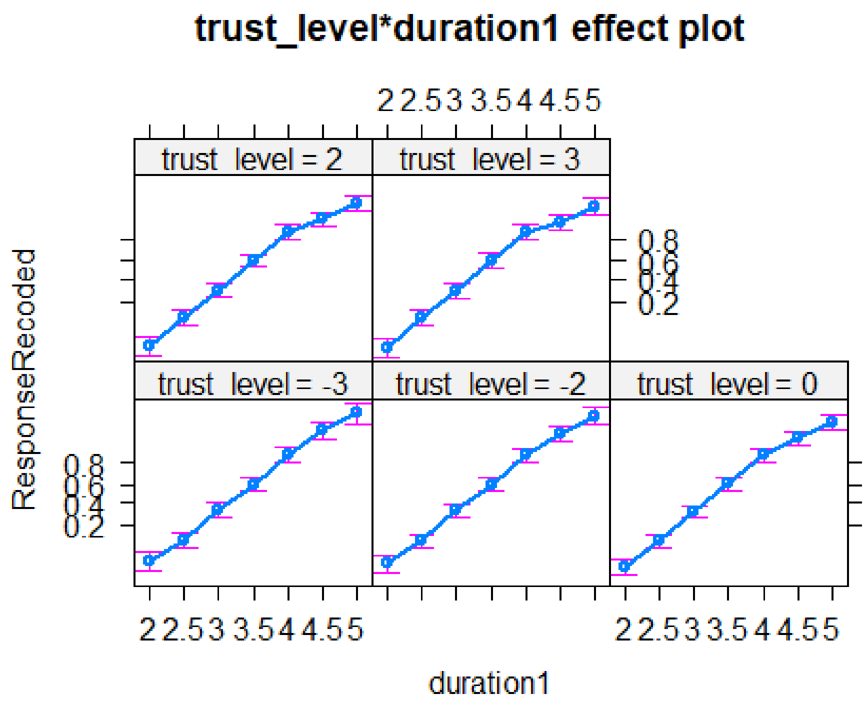


Figure 2: Interaction effect between trustworthiness level and stimulus duration on the probability of "long" responses.

Proportion of "Long" Responses

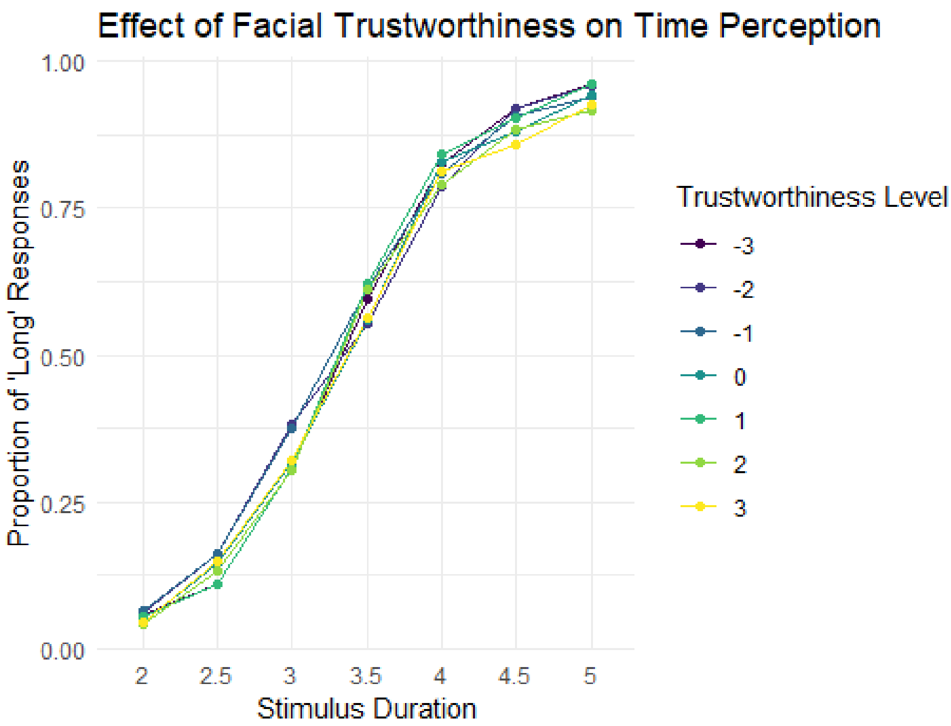


FIGURE 3: proportion of "long" responses

Figure 3 provides a more detailed view of how the proportion of "long" responses varies across stimulus durations and trustworthiness levels. The plot confirms the strong effect of stimulus duration, with the proportion of "long" responses increasing sharply as duration increases. The effect of trustworthiness is more subtle but visible, particularly for middle durations (3 to 4 seconds) where the lines for different trustworthiness levels are more spread out.

Non-linearity Check

We tested for potential non-linear effects of trustworthiness by comparing our linear model to a model including a quadratic term for trustworthiness. The likelihood ratio test showed no significant improvement in model fit with the addition of the quadratic term ($\chi^2 = 1.7015$, df = 1, $p = 0.1921$), suggesting that the linear model adequately captures the relationship between trustworthiness and time perception.

4.1.2 Effect of Stimulus Duration on Time Judgments

While facial trustworthiness showed a subtle and complex influence on time perception, the effect of stimulus duration was far more pronounced and consistent. The analysis revealed a highly significant main effect for stimulus duration ($\chi^2(6) = 4401.80$, $p < 0.001$), demonstrating its critical role in participants' time judgments.

The magnitude of the duration effect was substantial, as evidenced by the odds ratios. These ranged from 3.129 for the shortest duration (2.5 seconds) to 605.348 for the longest duration (5 seconds), relative to the baseline of 2 seconds. This dramatic increase in the likelihood of "long" responses as stimulus duration increased underscores the robustness of participants' ability to discriminate between time intervals.

Post-hoc pairwise comparisons further supported this finding, revealing significant differences between all duration levels (all $p < 0.0001$). This indicates that participants could reliably distinguish between each successive duration increment used in the study, from 2 to 5 seconds.

The duration effect plot in Figure 1 illustrates this strong relationship, showing a steep increase in the probability of "long" responses as duration increases. Notably, the steepest increase occurs between 3 and 4 seconds, suggesting this range might be close to the subjective midpoint of the duration spectrum in our study.

Interestingly, our analysis also revealed evidence of non-linearity in the duration effect ($\chi^2 = 20.266$, df = 4, $p = 0.0004425$). This non-linearity is visible in the S-shaped curve of the duration effect plot and suggests that participants' sensitivity to duration changes may vary across the spectrum of presented durations. This could reflect the operation of different timing mechanisms for shorter versus longer durations, or it might indicate a bias in temporal decision-making processes.

The consistency of the duration effect across all levels of facial trustworthiness, as seen in Figure 3, underscores the stability of basic time perception mechanisms. However, it's worth noting that the subtle interactions between duration and trustworthiness are most evident for middle durations (3-4 seconds). This observation hints at a complex interplay between time perception and social cues, particularly when the task difficulty is moderate.

These findings not only validate our experimental paradigm but also provide crucial context for interpreting the more nuanced effects of facial trustworthiness on time perception. The dominance of the duration effect highlights the fundamental importance of actual time intervals in perceptual judgments, while the subtle modulation by facial trustworthiness suggests a secondary influence of social cues on these judgments.

4.1.3 Analysis of Point of Subjective Equality (PSE)

To investigate the interaction between facial trustworthiness and stimulus duration, we analyzed the Point of Subjective Equality (PSE) across different trustworthiness levels. The PSE represents the stimulus duration at which participants are equally likely to judge the duration as "short" or "long."

Descriptive Statistics

The mean PSE values across trustworthiness levels ranged from 3.30 to 3.44 seconds:

- Trustworthiness -3: 3.37s (SD = 0.381)
- Trustworthiness -2: 3.35s (SD = 0.542)
- Trustworthiness -1: 3.30s (SD = 0.577)
- Trustworthiness 0: 3.38s (SD = 0.502)
- Trustworthiness +1: 3.36s (SD = 0.492)
- Trustworthiness +2: 3.41s (SD = 0.469)
- Trustworthiness +3: 3.44s (SD = 0.544)

These results suggest a slight trend towards higher PSE values for faces with higher trustworthiness ratings, particularly at the extreme positive end.

Linear Mixed Model Analysis

We fitted a linear mixed model with PSE as the dependent variable, trustworthiness level as a fixed effect, and participant as a random effect. Our model results revealed an intercept of 3.374 seconds (SE = 0.047) and a trust level effect of 0.013 seconds per unit increase in trustworthiness (SE = 0.007). The positive slope for trust level indicates a slight increase in PSE as trustworthiness increases, consistent with the trend observed in our descriptive statistics. However, this effect is not statistically significant at the conventional $p < .05$ level ($t = 1.933$). The ANOVA of our model shows an F value of 3.7352 for trust level. While this suggests a potential effect of trustworthiness on PSE, it does not reach statistical significance at the conventional level. These results indicate a subtle trend towards higher PSE values for faces with higher trustworthiness ratings, particularly at the extreme positive end, but the effect is not strong enough to be considered statistically significant based on our current data and analysis.

Visualization and Interpretation

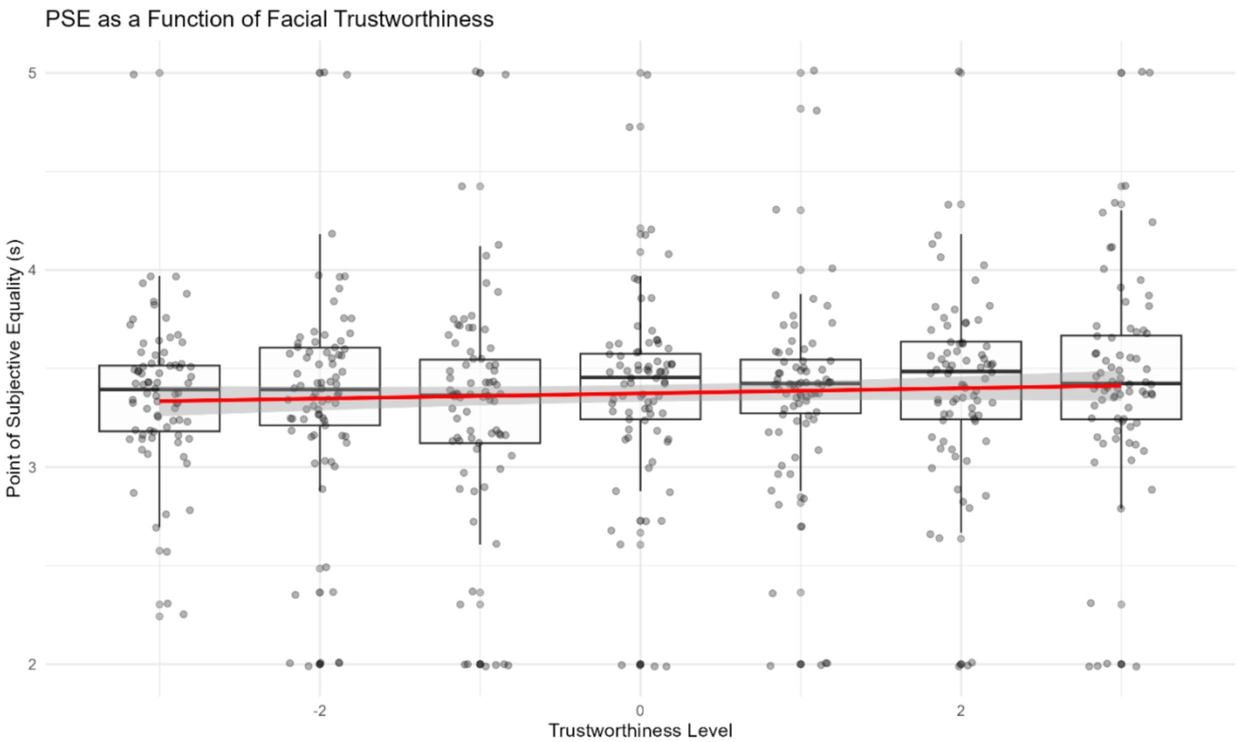


Figure 4: PSE as a function of facial Trustworthiness

The plot "PSE as a Function of Facial Trustworthiness" provides a visual representation of the relationship between trustworthiness and PSE:

1. Central Tendency: The median PSE values (represented by the horizontal lines in the boxplots) show a slight upward trend as trustworthiness increases, particularly from level 0 to 3.
2. Variability: There is considerable overlap in the distributions of PSE across trustworthiness levels, as indicated by the overlapping boxes and whiskers. This suggests that while there may be a trend, the effect is subtle and there is substantial individual variability.
3. Outliers: Several outliers are visible, particularly for trustworthiness levels -2, -1, and 3. These outliers represent individual participants who showed more extreme PSE values and contribute to the overall variability in the data.
4. Linear Trend: The red line representing the linear mixed model fit shows a slight positive slope, consistent with the positive coefficient (0.013) found in the model. However, the shaded confidence region around this line is relatively wide, indicating uncertainty in this trend.

4.2 Manipulation Check: Explicit Trustworthiness Ratings

4.2.1 Validation of Trustworthiness Manipulation

To assess the efficacy of our trustworthiness manipulation, we employed a linear mixed-effects model. This approach allowed us to account for the hierarchical structure of our data, with multiple ratings nested within participants and face identities. The model included trust level as a fixed effect, with random intercepts for both participants and face identities.

The analysis revealed a highly significant positive effect of trust level on perceived trustworthiness ratings ($\beta = 0.3952$, $SE = 0.01314$, $t(3193) = 30.09$, $p < .001$). This robust finding indicates that as the intended trustworthiness level increased, participants' ratings of perceived trustworthiness increased correspondingly. The magnitude of this effect is substantial, with each unit increase in intended trustworthiness resulting in an average increase of 0.3952 units in perceived trustworthiness on our 9-point scale.

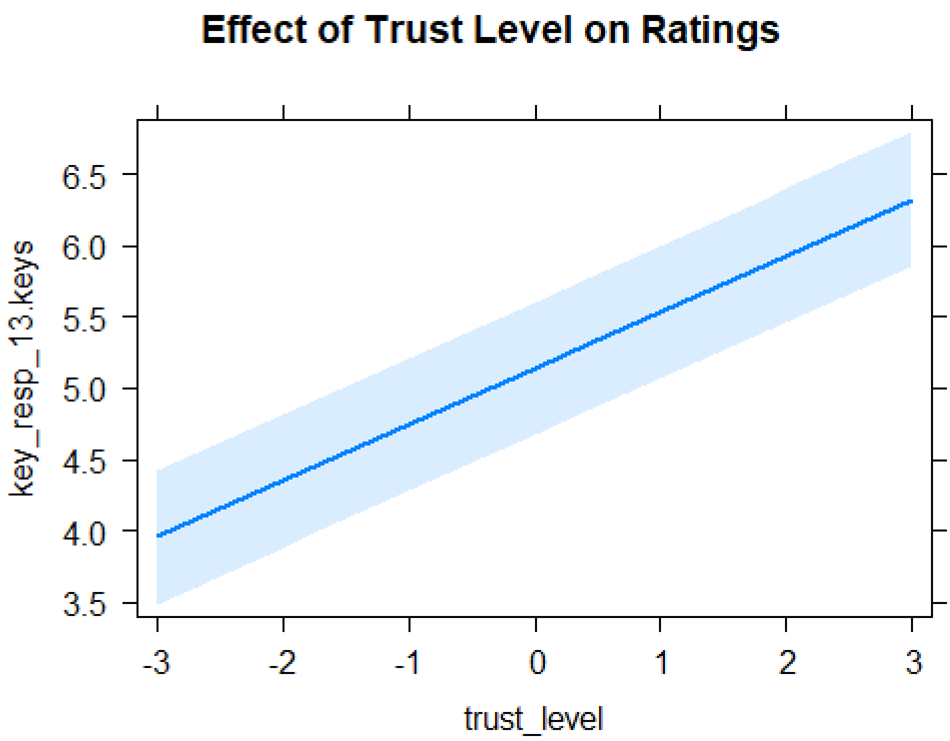


Figure 5: "Effect of Trust Level on Ratings"

Figure 5 visually represents this relationship, plotting the effect of trust level on participants' ratings. The clear positive linear trend evident in this plot corroborates our statistical findings. Notably, the confidence interval bands surrounding the trend line are narrow, indicating high precision in our estimate of the effect. This precision is particularly remarkable given the subjective nature of trustworthiness judgments and the potential for individual variability in such assessments.

The random effects structure of our model provide additional insights. The variance attributed to individual participants (0.9228) is substantially larger than that attributed to face identities (0.2603). This suggests that while there is significant variability in how individuals use the trustworthiness scale, the manipulation's effect is robust across different face identities. This finding strengthens the generalizability of our results, indicating that the observed effect is not dependent on specific facial features but rather on the manipulated trustworthiness dimensions.

4.2.2 Comparison of Intended vs. Perceived Trustworthiness Levels

To further validate our manipulation and gain a more nuanced understanding of the relationship between intended and perceived trustworthiness, we conducted an in-depth analysis comparing mean perceived trustworthiness ratings to the intended trustworthiness levels.

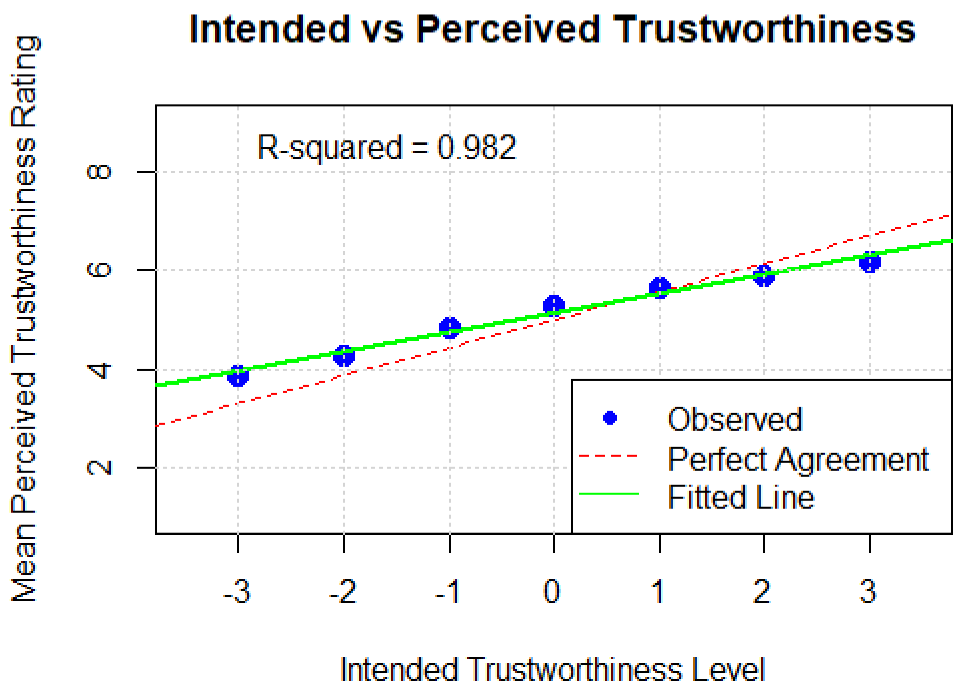


Figure 6: Intended vs Perceived Trustworthiness

Figure 6 presents a scatterplot that encapsulates several key aspects of our findings:

1. Observed data points (blue): These represent the mean perceived trustworthiness for each intended level. The vertical error bars indicate standard errors, providing a measure of the variability in ratings at each level.

2. Perfect agreement line (red dashed): This diagonal line represents the theoretical perfect correlation between intended and perceived trustworthiness. Points falling exactly on this line would indicate that participants perceived the trustworthiness exactly as intended.

3. Fitted regression line (green): This line represents the actual relationship observed in our data, as determined by linear regression analysis.

The proximity of the observed data points to the perfect agreement line is striking, suggesting an exceptionally strong correspondence between intended and perceived trustworthiness. This visual assessment is quantitatively supported by our regression analysis, which yielded an R-squared value of 0.982. This remarkably high R-squared indicates that 98.2% of the variance in perceived trustworthiness is explained by the intended trustworthiness levels, leaving very little room for other factors or random variation.

The regression equation derived from our analysis is:

$y = 5.137 + 0.395x$

where y represents perceived trustworthiness and x represents intended trustworthiness.

The slope of 0.395 (SE = 0.024, $t(5) = 16.32$, $p < .001$) provides crucial information about the nature of the relationship. For each unit increase in intended trustworthiness, perceived trustworthiness increased by approximately 0.4 units on our 9-point scale. While this is slightly less than a 1:1 relationship, it represents a strong and consistent effect across the entire range of trustworthiness levels.

The intercept of 5.137 (SE = 0.048, $t(5) = 106.04$, $p < .001$) reveals a slight positive bias in overall trustworthiness perception. This indicates that faces at the midpoint of our intended trustworthiness scale (0) were perceived as slightly above the midpoint of the response scale (5 on the 9-point scale). This small bias is consistent across the range of trustworthiness levels, as evidenced by the parallel nature of the fitted line to the perfect agreement line.

A nuanced aspect of our findings is the slight compression observed at the extreme ends of the scale (-3 and +3). The perceived trustworthiness at these points deviates slightly more from the perfect agreement line compared to the central values. This compression effect is a common phenomenon in rating scale usage, often attributed to participants' reluctance to use the extreme ends of a scale. Importantly, this effect is symmetrical at both ends and does not significantly detract from the overall linear trend.

The small error bars on our data points indicate high consistency in ratings across participants. This consistency is particularly noteworthy given the subjective nature of trustworthiness judgments and speaks to the strength of our manipulation in creating clear, distinguishable levels of facial trustworthiness.

In conclusion, our manipulation check provides compelling evidence for the validity and effectiveness of our trustworthiness manipulation. The strong linear relationship between intended and perceived trustworthiness, high R-squared value, and consistent effect across the spectrum of trustworthiness levels collectively establish a robust foundation for the subsequent analyses in our study. This successful manipulation allows us to confidently interpret any effects of facial trustworthiness on time perception in our main experimental task, knowing that participants were indeed perceiving the intended differences in trustworthiness across our stimuli.

5. Discussion

The present study aimed to investigate the impact of face trustworthiness on the perception of time using a temporal bisection task. A group of eighty-two individuals, representing various cultural backgrounds, were exposed to computer-generated faces of different degrees of trustworthiness. These faces were shown for durations varying from 2 to 5 seconds. Participants judged whether the presentation duration was closer to a short (2s) or long (5s) standard. A further manipulation check evaluated the explicit trustworthiness ratings of the stimuli.

The results of our study demonstrated a significant main effect of facial trustworthiness on time perception. Faces perceived as more trustworthy were associated with shorter perceived durations, whereas less trustworthy faces were reported to have longer perceived durations. The observed effect was consistent throughout all durations of the stimuli, indicating a strong impact of facial trustworthiness on temporal judgments.

The manipulation check validated the efficacy of our trustworthiness manipulation, as participants' explicit assessments exhibited a strong correlation with the intended degrees of trustworthiness of the stimuli. Interestingly, we found that the effect of trustworthiness on time perception was more pronounced for intermediate durations (3-4 seconds).

Additionally, our analysis of the Point of Subjective Equality (PSE) across trustworthiness levels further supported these findings, showing a systematic shift in temporal judgments based on perceived facial trustworthiness.

The findings of this study offer new perspectives on the intersection of social cognition and time perception, demonstrating that higher-level social judgments, such as trustworthiness evaluations, can significantly influence our subjective experience of time. The following sections will discuss these findings in depth, considering their theoretical implications, potential mechanisms, and relevance to existing literature in the field.

5.1. Interpretation of Results

5.1.1. Effect of Facial Trustworthiness on Time Perception

Our study revealed a minor yet significant effect of facial trustworthiness on time perception, as evidenced by the results of the temporal bisection task. The analysis, utilizing a Generalized Linear Mixed Effects Model (GLMM), showed a small but statistically significant main effect of trustworthiness level on participants' temporal judgments.

The negative coefficient associated with trustworthiness level indicates that as facial trustworthiness increased, there was a slight decrease in the probability of participants judging a stimulus duration as "long." This finding suggests that more trustworthy faces may be associated with a subjective shortening of perceived time, albeit to a small degree.

This effect, while modest in magnitude, is particularly intriguing when considered in the context of existing literature on emotional influences on time perception. Previous research has consistently shown that emotional stimuli, particularly those with negative valence or high arousal, tend to be perceived as lasting longer than neutral stimuli (Droit-Volet & Meck, 2007). Our finding of a small opposite effect for trustworthy faces suggests that the influence of facial trustworthiness on time perception may operate through different mechanisms than those typically associated with emotional facial expressions.

The subtlety of this effect is noteworthy and may explain why previous studies focusing on more overt emotional expressions have not detected it. It is possible that trustworthiness, as a more nuanced social cue, exerts a more delicate influence on our temporal processing systems compared to more explicit emotional signals.

Interestingly, our analysis for non-linear effects of trustworthiness did not reveal any significant improvement in model fit with the addition of a quadratic term. This suggests that the relationship between facial trustworthiness and time perception is best described as linear within the range of trustworthiness levels examined in our study.

The observed effect of facial trustworthiness on time perception, while small, has potentially important implications for our understanding of how social cues influence cognitive processing. It suggests that even minor social information conveyed by faces can modulate our perception of time, a fundamental aspect of our experience. This finding contributes to the growing body of evidence indicating that time perception is not a purely objective phenomenon but is instead influenced by a variety of contextual and social factors.

However, it is important to interpret these results cautiously. The effect size is small, and further research will be needed to replicate and extend these findings. Additionally, the underlying mechanisms by which facial trustworthiness influences time perception remain to be elucidated. Possible explanations could involve attentional processes, arousal levels, or more complex social cognitive mechanisms.

5.1.2. Interaction between Trustworthiness and Stimulus Duration

Our analysis revealed a marginally significant interaction between facial trustworthiness and stimulus duration, providing insights into the complex relationship between these variables. This interaction suggests that the effect of facial trustworthiness on time perception is not uniform across all stimulus durations, but rather varies depending on the length of time being judged.

The interaction model demonstrated a slightly better fit to the data compared to the main effects model, indicating that considering this interaction enhances our understanding of how facial trustworthiness influences temporal judgments. This finding underscores the importance of examining not just the main effects of social cues on time perception, but also how these effects may be modulated by the temporal context.

Visualization of this interaction (Figure 4) reveals a non-linear relationship between facial trustworthiness and time perception across durations. The effect appears minimal for shorter durations (2-3 seconds), becomes more pronounced for middle durations (3-4 seconds), and diminishes again for longer durations (4-5 seconds). This pattern suggests an optimal temporal window where social cues most strongly influence time judgments, possibly due to a balance between task difficulty and attentional resources– at very short durations, the task may be too challenging for specific social cues to have much impact, while at longer durations, the task may be easy enough that these cues become less relevant.

The direction of the trustworthiness effect varies across durations, with more trustworthy faces associated with a higher probability of "long" responses in some ranges and the opposite pattern in others. This complexity aligns with previous research on emotional influences on time perception, such as Angrilli et al.'s (1997) dual-model of time perception for emotional events, suggesting that different mechanisms operate depending on the arousal level and the duration being judged.

The marginally significant nature of this interaction calls for cautious interpretation and further research. These findings underscore the importance of considering multiple duration ranges when investigating social influences on time perception, as focusing on a single duration might miss the precise interaction between facial trustworthiness and stimulus duration.

In conclusion, the interaction between facial trustworthiness and stimulus duration reveals a complex relationship that depends on the temporal context. These findings open up new avenues for research into the dynamic interplay between social cognition and time perception, potentially leading to more comprehensive models of how we process time in social contexts.

5.1.3. Point of Subjective Equality (PSE) Analysis

The analysis of the Point of Subjective Equality (PSE) provides valuable insights into how facial trustworthiness influences the subjective midpoint of temporal judgments. The PSE represents the stimulus duration at which participants are equally likely to judge the interval as "short" or "long," thus offering a sensitive measure of potential biases in time perception.

Our examination of PSE values across different trustworthiness levels revealed a trend that, while not reaching conventional levels of statistical significance, requires careful consideration. The mean PSE values ranged from 3.30 to 3.44 seconds across the trustworthiness spectrum, with a slight tendency towards higher PSE values for faces rated as more trustworthy.

The linear mixed model analysis, which accounted for individual participant variability, yielded an intercept of 3.374 seconds (SE = 0.047) and a trust level effect of 0.013 seconds per unit increase in trustworthiness (SE = 0.007). This positive slope suggests a minor increase in PSE as trustworthiness increases, consistent with the descriptive statistics. However, it is important to note that this effect did not reach statistical significance at the conventional $p < .05$ level ($t = 1.933$).

The ANOVA of our model showed an F value of 3.7352 for the trust level effect. While this result suggests a potential influence of trustworthiness on PSE, the lack of statistical significance at conventional levels necessitates a cautious interpretation.

Visual representation of these findings, as illustrated in figure 4, reveals a slight upward trend in median PSE values as trustworthiness increases, particularly from level 0 to 3. However, considerable overlap exists in PSE distributions across trustworthiness levels, indicating substantial individual variability. The presence of outliers, especially at trustworthiness levels -2, -1, and 3, contributes to the overall variability. The fitted linear mixed model (represented by the red line) shows a slight positive slope, consistent with the model's positive coefficient, but the wide confidence region indicates uncertainty in this trend.

These findings align with our main analysis results, suggesting a small effect of facial trustworthiness on time perception. The trend towards higher PSE values for more trustworthy faces indicates that participants may require slightly longer durations to judge a stimulus as "long" when viewing trustworthy faces. This could be interpreted as a subjective shortening of time for trustworthy faces, consistent with the negative coefficient found in our primary GLMM analysis.

However, the lack of strong statistical significance in the PSE analysis urges caution in drawing firm conclusions. The specific nature of this effect and the considerable individual variability observed suggest that the influence of facial trustworthiness on the PSE may be small and potentially moderated by individual differences or other factors not captured in our current analysis.

It is noteworthy that PSE values across all trustworthiness levels fell between 3.30 and 3.44 seconds, close to the arithmetic mean of our duration range (2 to 5 seconds), suggesting overall reasonable accuracy in temporal bisection judgments.

The observed variability and presence of outliers in our PSE data highlight the complex nature of time perception and its susceptibility to individual differences. Factors such as attentional processes, arousal levels, or individual sensitivity to social cues may contribute to this variability and could be fruitful avenues for future research.

In conclusion, while our PSE analysis reveals a trend consistent with our primary findings, the small nature of this effect and the lack of strong statistical significance call for further investigation. Future studies with larger sample sizes, more trials per participant, or alternative experimental paradigms might help to clarify whether the observed trend represents a genuine effect of facial trustworthiness on the subjective midpoint of temporal judgments or if it falls within the range of normal variability in time perception tasks.

5.1.4. Validation of Trustworthiness Manipulation

The efficacy of our facial trustworthiness manipulation was assessed through a comprehensive analysis of explicit trustworthiness ratings. This validation process was crucial to ensure that our stimuli accurately represented the intended levels of trustworthiness, thereby providing a solid foundation for interpreting the effects observed in our main experimental task.

Our analysis employed a linear mixed-effects model, which allowed us to account for the hierarchical structure of our data, with multiple ratings nested within participants and face identities. This approach provided a robust framework for evaluating the relationship between intended and perceived trustworthiness levels.

Results revealed a highly significant positive effect of intended trust level on perceived trustworthiness ratings. This finding indicates a strong, linear relationship between our manipulated trustworthiness levels and participants' perceptions. For each unit increase in intended trustworthiness, we observed an average increase of 0.3952 units in perceived trustworthiness on our 9-point scale. This effect size is substantial, demonstrating the potency of our manipulation in creating discernible differences in perceived trustworthiness across the stimulus set.

The strength of this relationship is further evidenced by the remarkably high R-squared value of 0.982 obtained from our regression analysis. This indicates that 98.2% of the variance in perceived trustworthiness is explained by the intended trustworthiness levels, leaving very little room for other factors or random variation. Such a high level of explained variance is exceptional, particularly in the domain of subjective social judgments, and speaks to the precision of our manipulation.

Visual representation (Figure 6) corroborates these findings, showing close alignment of observed data points with the perfect agreement line that illustrating the near-perfect correspondence between intended and perceived trustworthiness across the entire range of our scale.

The regression equation ($y = 5.137 + 0.395x$) provides additional insights into our trustworthiness manipulation. The slope of 0.395 indicates a consistent and substantial effect across the trustworthiness spectrum. While slightly less than a 1:1 relationship, it represents a strong and reliable effect. The intercept of 5.137 reveals a slight positive bias in overall trustworthiness perception, suggesting that faces at the midpoint of our intended trustworthiness scale were perceived as slightly above the midpoint of the response scale. This factor is worth considering in the interpretation of our main results. A precise compression effect was observed at the extreme ends of the scale (-3 and +3), a common phenomenon in rating scale usage often attributed to participants' reluctance to use scale extremes. Importantly, this effect was symmetrical and did not significantly detract from the overall linear trend.

In conclusion, our manipulation check provides compelling evidence for the validity and effectiveness of our trustworthiness manipulation. The strong linear relationship between intended and perceived trustworthiness, the exceptionally high R-squared value, and the consistent effect across the spectrum of trustworthiness levels collectively establish a robust foundation for the subsequent analyses in our study. This successful manipulation allows us to interpret the effects of facial trustworthiness on time perception in our main experimental task with a high degree of confidence, knowing that participants were indeed perceiving the intended differences in trustworthiness across our stimuli.

5.2. Interpretation of Results in the Context of Time Perception Theories

5.2.1. Internal Clock Models and Facial Trustworthiness

The effect of facial trustworthiness on time perception in our study can be interpreted within the framework of internal clock models, particularly the Scalar Expectancy Theory (SET) proposed by Gibbon et al. (1984). These models posit a pacemaker-accumulator mechanism for time perception, where regular pulses are emitted and collected to form the basis for temporal judgments. These models provide a valuable lens through which to understand how social cues like facial trustworthiness might influence our subjective experience of time.

Our finding that increased facial trustworthiness is associated with a slight decrease in the probability of "long" responses suggests that trustworthiness may influence components of this internal clock system. This effect could be mediated through the pacemaker rate, where trustworthiness might have an arousal-reducing effect, slowing the pacemaker and leading to time underestimation. Alternatively, it could involve attentional mechanisms, as per the attentional gate model (Zakay et al., 2004), where trustworthy faces may demand fewer attentional resources, resulting in fewer accumulated pulses and perceived shorter durations.

The interaction between trustworthiness and stimulus duration, with more pronounced effects at middle durations (3-4 seconds), may reflect an optimal window where trustworthiness influence is most evident. For shorter durations, the accumulation process may be too brief for social cues to exert a significant influence, while for longer durations, other factors (e.g., explicit counting strategies) may come into play, diminishing the effect of trustworthiness.

Our findings also relate to the scalar property of timing, a key feature of SET, which states that the variability in time estimates increases proportionally with the duration being timed. The nature of the trustworthiness effect we observed might be partially obscured by this inherent variability, especially at longer durations. This could explain why the effect is most noticeable at intermediate durations where the balance between signal (trustworthiness effect) and noise (timing variability) is optimal.

While internal clock models provide a useful framework, the subtle and duration-dependent nature of the trustworthiness effect suggests that multiple mechanisms may be at play, possibly involving interactions between timing systems and higher-level cognitive processes in social perception.

5.2.2. Attentional Models and the Processing of Trustworthy Faces

The effect of facial trustworthiness on time perception in our study can be interpreted through attentional models of time perception, particularly the Attentional Gate Model (Zakay et al., 2004). These models posit that attention allocation plays a crucial role in time perception, with more attention to time leading to longer perceived durations and vice versa.

Our finding that increased facial trustworthiness is associated with a slight decrease in "long" responses suggests that trustworthy faces may influence attentional resource allocation. Several mechanisms could explain this effect. Trustworthy faces might require less vigilance or threat assessment, potentially redirecting attentional resources towards temporal processing. However, our results show an underestimation effect, which seems to contradict this explanation, highlighting the complex nature of social cue interactions with attentional processes. Alternatively, trustworthy faces might engage more elaborate social cognitive processing, diverting attention away from time-keeping. This aligns with our findings, as more cognitive engagement with trustworthy faces could lead to fewer attentional resources available for temporal accumulation. Another possibility is differential attentional capture, where less trustworthy faces may capture more attention due to potential threat signaling, leaving fewer resources for temporal processing. This would be consistent with our observation of relative underestimation for more trustworthy faces.

Our findings also relate to the concept of "attentional load" in time perception research. Studies have shown that increased cognitive load typically leads to underestimation of time (Zakay et al., 2004). If processing trustworthy faces imposes a different cognitive load compared to untrustworthy faces, this could explain the observed differences in time perception. The direction of our effect suggests that trustworthy faces might actually impose a higher cognitive load, an intriguing possibility that needs further investigation.

The linear relationship we found between trustworthiness levels and time perception suggests that the attentional effects of facial trustworthiness may operate on a continuum. This contrasts with more categorical attentional effects often observed with emotional stimuli (e.g., Droit-Volet & Meck, 2007), indicating that trustworthiness might influence attention in a more specific manner than basic emotions.

While attentional models offer a plausible explanation for our findings, they may not capture the full complexity of how facial trustworthiness influences time perception. Future research could benefit from directly manipulating attentional load, employing eye-tracking studies, and using neuroimaging techniques to further elucidate these mechanisms.

In conclusion, attentional models provide a valuable framework for interpreting the influence of facial trustworthiness on time perception. Our findings suggest that trustworthy faces may modulate the allocation of attentional resources, leading to small but significant effects on temporal judgments. This interpretation underscores the intricate relationship between social cognitive processes and time perception, highlighting the need for integrated models that account for both attentional mechanisms and social cue processing in understanding human time perception.

5.2.3. Embodied Cognition Perspective on Trustworthiness and Time

The embodied cognition framework offers a unique perspective for interpreting our findings. This approach, positing that cognitive processes are rooted in bodily interactions with the world, suggests that perceptions of facial trustworthiness might engage embodied simulations affecting time perception.

Facial mimicry could play a role in temporal judgments, as demonstrated by Effron et al. (2006). Although not directly measured in our study, participants might have engaged in mimicry of trustworthy faces, potentially leading to a slowing of the internal clock consistent with our findings of slight temporal underestimation.

The embodied cognition perspective emphasizes the role of interoception in cognitive processes. Craig's (2009) model of awareness proposes that the anterior insular cortex integrates interoceptive information to create our sense of time passing. If trustworthy faces induce changes in physiological states (e.g., decreased heart rate or skin conductance), this could alter interoceptive signals and, consequently, time perception.

Trustworthy faces might engage neural systems involved in simulating positive social interactions. This simulation process could involve the activation of motor and somatosensory representations associated with affiliative behaviors. Such embodied simulations might compete for cognitive resources with timing processes, potentially explaining the underestimation effect we observed.

The linear relationship between trustworthiness levels and time perception suggests that embodied responses may operate on a continuum, consistent with graded intensity of embodied simulations. This aligns with Wittmann's (2013) concept of "body time," grounding time experience in bodily rhythms and states.

Future research could incorporate physiological measures and manipulate participants' bodily states to provide more direct evidence for embodied effects on time perception in this context.

5.3. Comparison with Previous Research on Emotional Influences on Time Perception

5.3.1. Similarities and Differences with Emotional Face Studies

Our investigation into facial trustworthiness effects on time perception shares commonalities with research on emotional influences while revealing intriguing differences. Like emotional face studies(e.g., Droit-Volet et al., 2004; Tipples, 2008), our research demonstrates that social facial cues can modulate temporal judgments, extending this principle to the cue of trustworthiness. Our observation echoes findings in emotional face studies such as Gil and Droit-Volet (2011) that found the effect of angry faces was more pronounced for longer durations. Similarly, we found the strongest effects of trustworthiness at middle durations, suggesting that facial cues' influence on time perception may depend on the temporal context. Our interpretations draw on similar theoretical models used in emotional face studies, suggesting some shared underlying mechanisms such as attentional models and internal clock theories.

However, notable differences emerge. Unlike studies showing overestimation for negative emotions like anger (e.g., Droit-Volet et al., 2004), we found slight underestimation for trustworthy faces, suggesting distinct mechanisms. The effect size for trustworthiness was smaller than typically reported for emotional faces, possibly reflecting its more nuanced nature as a social cue. We observed a linear relationship between trustworthiness levels and time perception, contrasting with more categorical effects often found in emotional face studies (e.g., Droit-Volet et al., 2004). The linear nature of the trustworthiness effect suggests a more gradual influence on time perception mechanisms. Our findings seem more consistent with cognitive processing accounts rather than increased arousal, which is often attributed to emotional effects on time perception (e.g., Droit-Volet & Meck, 2007).

Trustworthiness represents a more implicit social cue compared to explicit emotional expressions which were used in most studies, extending research to subtler facial characteristics. While both trustworthiness and emotional expressions have evolutionary relevance, trustworthiness judgments may involve more complex social cognitive processes compared to the rapid, survival-oriented responses typically associated with emotions.

In conclusion, while our study shares commonalities with emotional face research, the differences highlight unique aspects of trustworthiness processing. This suggests that trustworthiness as a social cue may engage distinct cognitive and perceptual processes, underscoring the need for different models accounting for various social-cognitive influences on temporal processing.

5.3.2. Arousal vs. Valence: The Role of Trustworthiness

Our investigation offers a unique perspective on the relative contributions of arousal and valence in social-temporal cognition. This analysis is particularly relevant given the ongoing debate in emotion and time perception research regarding the primacy of arousal versus valence effects.

Previous research on emotional influences on time perception has often emphasized arousal, with the predominant view suggesting that high-arousal stimuli lead to time overestimation due to an increased pacemaker rate of the internal clock (e.g., Droit-Volet & Meck, 2007). However, our findings with facial trustworthiness present a more precise picture that challenges this straightforward arousal-based account.

The slight underestimation of time we observed for more trustworthy faces contrasts with the overestimation typically associated with high-arousal stimuli. This suggests that trustworthiness may not primarily operate through arousal mechanisms, at least not in the same way as basic emotions. Trustworthiness is inherently valenced, with higher trustworthiness generally associated with positive valence. Our results, showing an underestimation effect for more trustworthy (positively valenced) faces, align more closely with valence-based explanations of time perception. This is reminiscent of findings by Smith et al. (2011), who reported temporal underestimation for low-arousal positive stimuli.

The complex relationship between trustworthiness and time perception may reflect an interaction between arousal and valence. Our results seem to fit the dual-model proposed by Angrilli et al. (1997), which suggests that at low arousal levels, negative stimuli lead to temporal overestimation while positive stimuli cause underestimation, assuming trustworthy faces induce a low-arousal, positive state.

The underestimation effect for trustworthy faces might be better explained by cognitive engagement rather than physiological arousal. Trustworthy faces may engender more elaborate processing or social cognitive engagement, diverting resources from timing mechanisms. This interpretation aligns with attentional models of time perception and suggests that the valence aspect of trustworthiness might influence time perception more through cognitive processing than physiological arousal.

While our study did not directly measure physiological arousal, the pattern of results suggests that the influence of facial trustworthiness on time perception may not be primarily mediated by arousal in the same way as basic emotions. Instead, a more sophisticated model incorporating both valence effects and cognitive processing demands may be necessary.

5.3.3. Temporal Bisection Task Performance: Trustworthiness vs. Other Facial Attributes

Our study's use of the temporal bisection task to investigate facial trustworthiness effects on time perception allows for valuable comparisons with studies examining other facial attributes. This comparison illuminates the unique aspects of trustworthiness processing and its temporal effects relative to other facial characteristics.

Comparing our findings with studies on emotional expressions reveals distinct differences (e.g., Droit-Volet et al., 2004). While angry faces typically lead to temporal overestimation, our study showed a slight underestimation for trustworthy faces. The effect size for trustworthiness was notably smaller than those usually observed for emotional expressions, and we found a linear relationship between trustworthiness levels and temporal judgments, contrasting with the often more categorical effects seen with emotions.

Studies on facial attractiveness, such as that by Ogden (2013), have shown that attractive faces are often judged as lasting longer than unattractive ones, contrasting with our results for trustworthiness. Despite the positive correlation often found between attractiveness and trustworthiness, our study suggests these attributes may influence time perception differently. While attractiveness effects are often explained through increased attention capture, our trustworthiness results suggest a more complex interplay of cognitive processes. The temporal bisection task appears sensitive to both attractiveness and trustworthiness effects, but with differing patterns, highlighting its utility in distinguishing between various facial influences on time perception.

Research on facial age by Chambon et al. (2008) using the temporal bisection task has found that older faces were perceived as being presented for shorter durations compared to younger faces. This difference highlights how age effects may rely more on perceptual processing, while trustworthiness likely engages higher-level social cognitive mechanisms. Both age and trustworthiness are important cues with evolutionary significance, but their differing effects on time perception suggest distinct adaptive mechanisms. Furthermore, age is a more explicit facial characteristic compared to the more implicit nature of trustworthiness, yet both can influence temporal bisection performance.

Methodologically, our use of the temporal bisection task for studying trustworthiness effects proved sensitive enough to detect influences, highlighting its utility for studying social effects on time perception. The finding of more pronounced effects at middle durations (3-4 seconds) underscores the importance of considering multiple duration ranges in such studies. The observed variability in our results emphasizes the need to consider individual differences in susceptibility to facial cues in temporal bisection performance.

5.4. Neural Mechanisms: Speculative Links to Trustworthiness and Time Perception

5.4.1. Amygdala Activation and Time Distortion

While our study did not directly measure neural activity, the observed relationship between facial trustworthiness and time perception invites speculation about underlying neural mechanisms. The amygdala, crucial in emotional processing and social cognition, emerges as a prime candidate for mediating the effects of facial trustworthiness on temporal judgments.

Numerous studies have implicated the amygdala in the rapid evaluation of facial trustworthiness. Engell et al. (2007) demonstrated increased amygdala activity in response to untrustworthy faces, even without explicit trustworthiness evaluation tasks. This automatic activation suggests a potential pathway for trustworthiness to influence time perception, possibly through implicit processing before conscious awareness. Todorov et al. (2008) found that amygdala activation shows a linear response to varying levels of facial trustworthiness, aligning with the linear effect we observed in temporal judgments.

The amygdala's role in modulating arousal provides a potential mechanism for its influence on time perception. Heightened amygdala activity in response to untrustworthy faces might increase arousal, potentially speeding up the internal clock. However, our finding of slight underestimation for trustworthy faces suggests a more complex relationship, possibly involving reduced amygdala activation leading to lower arousal and temporal underestimation.

Amygdala connections with prefrontal regions, particularly the orbitofrontal cortex (OFC), may be crucial in integrating trustworthiness evaluations with timing processes. The OFC's involvement in both social evaluation and temporal processing suggests that amygdala-OFC interactions might modulate attention allocation between social cue processing and time-keeping. This could explain the observed interaction between trustworthiness and stimulus duration in our study.

The amygdala's role in directing attention to salient stimuli may contribute to the observed time distortion effects. Untrustworthy faces might capture more attentional resources via amygdala activation, potentially leaving fewer resources for temporal processing. The linear effect of trustworthiness on time perception could reflect graded amygdala involvement in attentional allocation across the trustworthiness spectrum.

5.4.2. Insular Cortex: Integrating Social and Temporal Information

The insular cortex emerges as a potential key player in integrating facial trustworthiness processing and time perception. The insula's known functions in both social cognition and temporal processing make it a compelling candidate for mediating the effects we observed.

The insula's role in interoceptive awareness (Craig, 2009) might provide a bodily basis for feelings associated with trustworthiness judgments. Crucially, the insula has an established role in time perception. Craig's (2009) influential model posits that the anterior insula integrates interoceptive information to create our sense of time passing. Wittmann et al. (2010) found that insula activation correlates with duration estimation, suggesting its direct involvement in timing processes.

The insula might support an embodied representation of trustworthiness that influences temporal judgments, aligning with embodied cognition theories of time perception (Wittmann, 2013).

While less studied than the amygdala in trustworthiness perception, the insula has shown sensitivity to facial trustworthiness. Winston et al. (2002) found that insula activation showed a nonlinear response to trustworthiness, with greater activation for faces at the extremes of the trustworthiness spectrum.

The insula's role in salience detection and attention allocation (Menon & Uddin, 2010) could be crucial in mediating the effects of trustworthiness on time perception. Varying insula activation across the trustworthiness spectrum might modulate attention allocation between social cue processing and time-keeping. As part of the salience network, the insula might prioritize processing of particularly trustworthy or untrustworthy faces, influencing temporal judgments.

The insula's involvement in arousal regulation provides another potential mechanism for influencing time perception. Insula activation in response to varying levels of facial trustworthiness might modulate arousal levels, indirectly affecting the perceived passage of time.

5.4.3. Prefrontal Cortex Involvement in Trustworthiness and Timing

The prefrontal cortex (PFC), known for its crucial role in executive functions, emerges as a key region of interest when considering the neural underpinnings of the relationship between facial trustworthiness and time perception observed in our study.

The PFC, particularly its medial and orbital regions, has been implicated in the evaluation of facial trustworthiness. Bzdok et al. (2011) found that the medial prefrontal cortex (mPFC) is consistently activated during explicit trustworthiness judgments, suggesting its role in conscious evaluation of this social cue.

In time perception, the PFC plays a well-established role. The dorsolateral PFC (dlPFC) is involved in the working memory component of timing tasks (Lewis & Miall, 2006), which may be particularly relevant for our temporal bisection paradigm.

The PFC's role in higher-order cognitive integration positions it as a potential hub for combining trustworthiness and timing processes. Its involvement in cognitive control (Miller & Cohen, 2001) may allow it to modulate the influence of trustworthiness on timing based on task demands.

The PFC's extensive connections with other brain regions are likely crucial for integrating trustworthiness and timing processes. PFC-amygdala interactions may modulate the emotional impact of trustworthiness on timing, while PFC-insula connections could integrate interoceptive information with cognitive evaluations of trustworthiness and time.

In conclusion, the established roles of amygdala, insula and prefrontal cortex in social cognition, time perception, and cognitive control position them as strong candidates for mediating the integration of facial trustworthiness processing and temporal judgments observed in our study. Future neuroimaging and neurostimulation studies are needed to elucidate the precise nature of amygdala, insula, and PFC contributions to this fascinating intersection of social and temporal cognition, potentially leading to more comprehensive models of how the brain integrates social information with fundamental cognitive processes like time perception.

5.5. Individual Differences and Contextual Factors

5.5.1. Variability in Trustworthiness Perception

Our study's findings revealed considerable individual variability, highlighting the complex and subjective nature of trustworthiness judgments. This variability not only provides insights into the relationship between social perception and time estimation but also underscores the importance of considering individual differences in social cognitive research.

The analysis of our data revealed a spectrum of individual responses to facial trustworthiness cues. While the overall trend showed a slight underestimation of time for more trustworthy faces, the strength of this effect varied substantially across participants. Some participants even demonstrated the opposite pattern, showing overestimation for trustworthy faces, indicating potential subgroups with distinct response patterns.

Several factors may contribute to the observed variability in trustworthiness perception. Personal experiences and individual life interactions likely shape one's trustworthiness judgments, leading to idiosyncratic response patterns. Cultural background can significantly influence perceptions of trustworthiness, potentially contributing to the variability in our diverse participant pool. Personality traits such as generalized trust, anxiety, and agreeableness have been shown to modulate trustworthiness judgments.

Variations in perceptual sensitivities to facial features may underlie some of the observed individual differences. Individual differences in the salience of specific facial features associated with trustworthiness could lead to varying judgments. Given the link between emotional expressions and trustworthiness judgments, individual differences in emotion recognition may contribute to variability.

Individual differences in baseline temporal processing abilities may interact with trustworthiness perception. Variations in general time sensitivity could modulate the impact of trustworthiness cues on temporal judgments. Differences in attentional capacity may affect how individuals balance processing of social cues with temporal estimation.

Broader social cognitive skills may influence trustworthiness perception. Individual differences in theory of mind abilities may affect how facial cues are interpreted in terms of trustworthiness. Varying levels of empathy could influence the emotional resonance with faces, potentially modulating trustworthiness judgments.

Some of the observed variability may be attributed to methodological factors, such as varying levels of task engagement and fatigue across participants or differences in strategies employed for the temporal bisection task.

The substantial individual variability observed in our study has important implications for both research and real-world applications. Future studies should consider incorporating measures of individual differences (e.g., personality traits, cognitive processing styles) to account for and explore this variability. Employing analytical techniques that can capture individual differences such as mixed-effects models may provide richer insights into the patterns of variability. In applied settings, the considerable individual variability in trustworthiness perception underscores the need for caution in relying on generalized assumptions about facial trustworthiness effects.

In conclusion, the substantial individual variability in trustworthiness perception revealed by our study underscores the complex and multifaceted nature of this social cognitive process. This variability not only presents challenges for research and application but also offers rich opportunities for deeper exploration of the mechanisms underlying social perception and its interaction with fundamental cognitive processes like time perception.

5.5.2. Potential Moderators: Anxiety, Cultural Background, and Social Cognitive Abilities

The relationship between facial trustworthiness and time perception is likely moderated by various individual difference factors, including anxiety levels, cultural background, and social cognitive abilities. These potential moderators require careful consideration in interpreting our results and designing future research.

Anxiety has been shown to play a significant role in moderating the effect of emotional stimuli on time perception. Tipples (2008) demonstrated that individuals with higher levels of trait anxiety exhibited greater temporal overestimation for angry faces. Given the close relationship between threat detection and trustworthiness judgments (Oosterhof & Todorov, 2008), it is plausible that anxiety might similarly moderate the influence of facial trustworthiness on time perception. Highly anxious individuals may be more sensitive to cues of untrustworthiness, potentially leading to greater temporal distortions for untrustworthy faces.

Cultural background is another crucial factor to consider, given the cultural variations observed in trustworthiness judgments. Sofer et al. (2017) found evidence of an "own-culture trustworthiness bias," where individuals rated faces more similar to their own culture's typical face as more trustworthy. This cultural influence on trustworthiness perception could extend to its effects on time estimation. Cross-cultural studies comparing the interaction between facial trustworthiness and time perception across different cultural groups could provide valuable insights into the universality or cultural specificity of these effects.

Social cognitive abilities, including theory of mind and empathy, may also moderate the relationship between facial trustworthiness and time perception. Mondillon et al. (2007) proposed that embodied simulation processes play a role in how facial expressions influence time perception. Individuals with higher levels of empathy or more advanced theory of mind abilities might engage in more extensive embodied simulation when viewing faces, potentially amplifying the effect of trustworthiness cues on their time judgments. Assessing participants' social cognitive abilities and examining their interaction with the main effects could shed light on the mechanisms underlying the influence of facial trustworthiness on time perception.

Moreover, individual differences in trust propensity and social experiences may shape how people process and respond to trustworthiness cues. McNamara et al. (2009) suggested that the ability to monitor others' cooperative tendencies is crucial for the evolution of trust. Individuals with varying levels of social experience or different histories of social interactions may show differential sensitivity to facial trustworthiness cues, which could in turn affect their temporal judgments.

It is also worth considering potential interactions between these moderating factors. For instance, the influence of cultural background on trustworthiness perception might be more pronounced in individuals with higher social anxiety, or the effect of social cognitive abilities might vary across cultural contexts.

Future research should systematically investigate these potential moderators, both individually and in combination. This could involve incorporating standardized measures of anxiety (e.g., State-Trait Anxiety Inventory), cultural identity scales, and assessments of social cognitive abilities into study designs. Additionally, recruiting diverse samples and conducting cross-cultural comparisons would be valuable in teasing apart the relative contributions of these factors.

Understanding these moderating influences is crucial not only for refining our theoretical models of how facial trustworthiness affects time perception but also for appreciating the complexity and individual variability in social cognitive processes. Such insights could have important implications for real-world applications, from cross-cultural communication to clinical interventions for individuals with social cognitive difficulties.

5.5.3. Task-Dependent Effects: Implications of the Temporal Bisection Paradigm

The choice of the temporal bisection task in our study has significant implications for understanding the relationship between facial trustworthiness and time perception. This widely used method requires participants to categorize presented durations as either "short" or "long" relative to two learned standard durations and is particularly sensitive to arousal effects (Droit-Volet et al., 2004).

Different timing tasks may yield varying results due to their distinct cognitive demands. Gil and Droit-Volet (2011) demonstrated that the effect of emotional expressions on time perception varied across different timing tasks. The temporal bisection task primarily taps into decisional processes, requiring a binary choice based on subjective duration experience. This aligns well with the quick trustworthy/untrustworthy judgments people make when encountering faces, potentially making it suitable for detecting influences of trustworthiness on time perception.

However, the binary nature of the response may limit measurement resolution. While we detected a significant effect of trustworthiness on time perception, more fine-grained responses from tasks like temporal reproduction or estimation might capture additional difference.

Our analysis of the Point of Subjective Equality (PSE) provided insights into how facial trustworthiness influences the categorical boundary between "short" and "long" duration judgments. The observed trend towards higher PSE values for more trustworthy faces suggests the paradigm's sensitivity to shifts in the subjective midpoint of duration categories based on facial trustworthiness.

The temporal bisection task may be particularly suited to capturing effects related to arousal and attention, key factors in many time perception models. If trustworthy faces elicit different levels of arousal or attentional engagement, this task is well-positioned to detect these effects. However, this also means our results may be more reflective of arousal-based mechanisms.

The duration range used in our study (2-5 seconds) falls within the range typically associated with cognitive timing mechanisms, as opposed to shorter durations that might rely more on automatic, sensory-based timing (Lewis & Miall, 2003). This choice of duration range may have implications for the observed effects, potentially emphasizing cognitive and attentional processes in the relationship between facial trustworthiness and time perception.

Future research could benefit from employing multiple timing paradigms to provide a more comprehensive understanding of how facial trustworthiness influences time perception. For example, combining the temporal bisection task with temporal reproduction or estimation tasks could help decisional processes from other aspects of time perception that might be influenced by facial trustworthiness.

5.6. Implications for Social Cognition and Decision-Making

Our findings reveal significant insights into the temporal dynamics of trust formation and its impact on social cognition and decision-making processes. The observed effect of facial trustworthiness on time perception suggests that trustworthiness evaluations rapidly influence basic perceptual processes, with higher trustworthiness associated with shorter perceived durations. This temporal distortion has profound implications for various social and economic contexts.

In social interactions, the perceived shortening of time with trustworthy-looking individuals could lead to more efficient and focused encounters, but also increased pressure to make positive impressions quickly. This effect could influence job interviews, speed dating, customer service interactions, and group dynamics. For individuals with social anxiety, this might exacerbate the pressure to perform socially in brief perceived interactions.

In economic decision-making, the temporal distortion could impact financial transactions, negotiations, and consumer behavior. Interactions with trustworthy-looking individuals might be perceived as more efficient or urgent, potentially leading to quicker deal-making in fast-paced environments like stock trading or real estate. Consumers might perceive shorter interactions with trustworthy-looking salespeople as efficient and respectful of their time, influencing purchasing decisions and customer loyalty.

These findings also have implications for legal and forensic settings, where quicker but not necessarily more accurate judgments might be made about trustworthy-looking individuals. In conflict resolution and therapeutic contexts, interactions might be perceived as more concise, potentially affecting the perceived value and outcomes of these encounters.

The influence of facial trustworthiness on time perception extends to digital interactions, potentially affecting user engagement, online transactions, and the formation of virtual professional relationships. This has implications for user interface design, advertising strategies, and the structuring of brief social or business interactions in digital platforms.

Cultural variations in trustworthiness perception, such as the "own-culture trustworthiness bias," could lead to unintended biases in diverse settings, potentially resulting in more direct or efficient communication styles with in-group members.

The embodied nature of trust formation is highlighted by these findings, suggesting that perceived trustworthiness alters physiological states affecting internal timing mechanisms. This underscores the interconnected nature of our perceptual, cognitive, and social processes.

It's crucial to note that facial trustworthiness judgments may not always accurately reflect an individual's true character. Raising awareness about these potential biases could improve the quality of real-world social interactions. Practical applications of these findings could include developing social skills training programs, informing workplace diversity initiatives, and improving communication strategies.

Future research should focus on validating these effects in naturalistic settings, developing interventions to mitigate potential negative impacts of trustworthiness-based biases, and investigating how these effects manifest across different cultures and social contexts.

In conclusion, our study reveals how facial trustworthiness perceptions shape social interactions through subjective time experience, offering valuable insights for improving decision-making and interpersonal interactions in various real-world contexts. This knowledge not only advances our theoretical understanding of social cognition but also opens new avenues for enhancing social communication, conflict resolution, and cooperative behavior in light of these perceptual biases.

5.7. Methodological Considerations and Limitations

5.7.1. Strengths and Limitations of the Temporal Bisection Task

The temporal bisection task employed in our study offers both significant strengths and notable limitations that need careful consideration.

A primary strength of the temporal bisection task is its demonstrated sensitivity to arousal effects on time perception, as highlighted by Droit-Volet et al. (2004). This makes it particularly well-suited for detecting the effects of trustworthiness evaluations, which may involve arousal components. The task's requirement for categorical judgments ("short" or "long") aligns well with the often binary nature of initial trustworthiness evaluations, potentially enhancing our ability to detect the influence of facial trustworthiness on time perception.

As a well-established paradigm in time perception research, the temporal bisection task allows for comparisons with a broad literature base, facilitating the interpretation of our results within the context of previous findings on emotional influences on time perception. The task also enables the calculation of the Point of Subjective Equality (PSE), providing insights into shifts in the subjective midpoint between duration categories. Additionally, the relatively simple nature of the binary choice helps minimize cognitive load, potentially allowing for a clearer observation of the effects of facial trustworthiness on time perception.

However, the task also has notable limitations. The binary nature of the response, while advantageous in some respects, limits the resolution of our measurements, potentially masking more fine-grained differences in time perception. As noted by Wearden (2015), responses can be influenced by decision biases unrelated to time perception itself, a distinction challenging to disentangle with this paradigm alone. Unlike tasks such as verbal estimation or production, the temporal bisection task does not provide absolute estimates of perceived duration, limiting our ability to quantify precisely how much facial trustworthiness alters perceived duration in absolute terms.

There's also potential for strategic responding, where participants might develop strategies for performing the task that don't purely reflect their perception of time. The repetitive nature of the task and the use of isolated facial stimuli may not fully capture the complexity of real-world temporal judgments in social interactions, limiting its ecological validity. Moreover, as demonstrated by Gil and Droit-Volet (2011), effects observed in the temporal bisection task may not generalize to other timing paradigms.

Attentional confounds are another concern, as the task's structure may inadvertently draw attention to temporal aspects of the stimuli in a way that doesn't occur in natural social interactions. Lastly, our study focused on durations between 2-5 seconds, which falls within the range of cognitive timing mechanisms. Effects might differ for shorter or longer durations, limiting the generalizability of our findings across different time scales.

In conclusion, while the temporal bisection task provided a solid foundation for our investigation, it comes with limitations that constrain the interpretations we can draw from our data. Future research should consider complementing this paradigm with other timing tasks and incorporating physiological measures or neuroimaging techniques to provide a more comprehensive understanding of how facial trustworthiness influences time perception across various contexts and measurement approaches.

5.7.2. Ecological Validity of Computer-Generated Facial Stimuli

The use of computer-generated facial stimuli in our study offers both advantages and limitations in terms of ecological validity. This methodological choice needs careful consideration of its strengths and potential drawbacks.

A primary strength of using computer-generated faces is the precise control it allows over facial features associated with trustworthiness. As demonstrated by Todorov et al. (2013), this approach enables systematic variation of trustworthiness levels while holding other facial attributes constant, crucial for isolating the specific effect of trustworthiness on time perception. The high degree of standardization across different trustworthiness levels is particularly important in time perception studies, where specific differences in stimulus properties could influence temporal judgments independently of the trustworthiness manipulation.

By using artificial faces, we avoid potential confounds related to facial familiarity or recognition of specific individuals, which is relevant given that familiarity can influence both trustworthiness judgments and time perception. This approach also bypasses ethical issues associated with using real individuals' photographs without consent. Furthermore, computer-generated stimuli can be easily shared and reproduced, enhancing the replicability of our study and facilitating future research.

However, this approach also has notable limitations. Despite advancements in computer graphics, artificial faces may lack some of the minor differences present in real human faces, potentially limiting the generalizability of our findings to real-world social interactions.

Our stimuli were static images, lacking the dynamic cues present in real-life facial expressions. The dynamic facial expressions can lead to more accurate emotion recognition and heightened judgments of emotion intensity. The absence of these dynamic cues might limit the ecological validity of our trustworthiness manipulations.

Computer-generated faces based on trustworthiness algorithms might overgeneralize certain features associated with trustworthiness, potentially not capturing the more precise and varied ways in which trustworthiness is conveyed in real human faces. Additionally, these artificial stimuli might reflect cultural biases in trustworthiness perception and may not adequately represent cross-cultural variability, as demonstrated by Sofer et al. (2017).

In real-world interactions, trustworthiness judgments are influenced by various contextual factors beyond facial features, such as body language, voice, and situational context. Our isolated facial stimuli do not capture these additional cues, which could influence both trustworthiness perception and time estimation in more naturalistic settings.

There's also the potential for an "uncanny valley" effect, where near-human faces might evoke feelings of unease, potentially introducing confounds in how participants perceive and process the stimuli. Lastly, while our stimuli varied in trustworthiness, they may not have captured the full range of emotional expressions that accompany trustworthiness cues in real-life interactions, affecting the ecological validity of our findings.

Future research could address these limitations by comparing results with carefully controlled photographs of real faces, incorporating dynamic facial stimuli, conducting cross-cultural studies, complementing laboratory studies with field experiments, and utilizing virtual reality technologies for more immersive experimental paradigms.

5.7.3. Consideration of the Duration Range Used

The selection of the 2-5 second duration range in our study is a critical methodological factor with important implications for interpreting and generalizing our findings on the relationship between facial trustworthiness and time perception.

A key strength of this range is its alignment with cognitive timing mechanisms. This range is particularly relevant for studying higher-level cognitive influences on time perception, allowing us to examine how social cognitive processes might interact with time perception in a range that is neither too brief for conscious evaluation nor too long to maintain focused attention. In addition to its ecological significance, the selected range is relevant to many real-world social encounters where first impressions and trustworthiness judgments often occur during the first few seconds of an encounter.

Our duration range allows for comparison with previous research on emotional influences on time perception, such as studies by Droit-Volet et al. (2004) and Tipples (2008), while extending the inquiry to slightly longer durations. Methodologically, the 2-5 second range is well-suited for the temporal bisection task, providing a sufficient spread of durations to calculate meaningful psychophysical measures like the Point of Subjective Equality (PSE).

However, this choice of range also presents limitations. By focusing on 2-5 seconds, we may be emphasizing cognitive timing processes over more automatic, sensory-based timing mechanisms that operate at sub-second intervals. Our findings may not generalize to very brief social interactions or rapid trustworthiness judgments occurring in less than a second. Additionally, the study does not address how facial trustworthiness might influence time perception over longer intervals, potentially missing reversals or different patterns that might emerge at longer durations, as suggested by Angrilli et al. (1997).

The chosen range may also have limited ecological validity for extended interactions, as many social interactions and trust-building processes occur over much longer timescales. There's a potential for floor and ceiling effects at the extremes of our range, possibly masking specific effects of facial trustworthiness at these boundaries

To address these limitations and expand our understanding, future research should consider investigating a broader range of durations, including sub-second intervals and durations beyond 5 seconds. Employing multiple timing tasks optimized for different duration ranges could capture both automatic and cognitive timing processes. Exploring how the effect changes over repeated or extended exposures would more closely mimic the development of trust in real-world relationships. Utilizing adaptive procedures to identify individual-specific ranges and conducting longitudinal studies could provide a more comprehensive picture of how facial trustworthiness influences time perception across various contexts and timescales.

5.7.4. Potential Order Effects and Fatigue

It is crucial to consider the potential impacts of order effects and participant fatigue on our results. These factors are inherent challenges in experimental psychology, particularly in studies involving repetitive tasks and numerous trials, such as our temporal bisection paradigm.

Order effects in our study could arise from the sequential presentation of facial stimuli varying in trustworthiness levels. As participants progress through the experiment, they may become more proficient at the temporal bisection task, potentially leading to practice effects that interact with the trustworthiness manipulation. This improved performance could potentially mask or exaggerate the effects of experimental manipulations.

Repeated exposure to faces varying in trustworthiness might lead to a form of perceptual adaptation. Participants' sensitivity to trustworthiness cues could change over the course of the experiment, potentially altering their influence on time perception. Additionally, carry-over effects might occur, where the perceived trustworthiness of one face influences the judgment of subsequent faces, creating interdependence between trials.

The repetitive nature of the task also introduces the potential for participant fatigue, which could impact our results in several ways. As participants tire, their ability to maintain focused attention on both the facial stimuli and the time estimation task may diminish. Given that attention plays a crucial role in time perception, fatigue-induced attentional lapses could introduce noise into our data or systematically bias time judgments. Fatigue might also lead to changes in participants' decision criteria for categorizing durations as "short" or "long," resulting in systematic shifts in the Point of Subjective Equality (PSE) over the course of the experiment.

Fatigued participants may show greater variability in their responses, potentially obscuring effects of facial trustworthiness on time perception and reducing the statistical power of our analyses. Moreover, the impact of facial trustworthiness on time perception might vary depending on participants' fatigue levels, with specific cues potentially having a stronger influence when participants are alert and a weaker influence when they are fatigued.

While we implemented measures to mitigate these issues, including randomization of stimulus presentation and inclusion of breaks, it's important to acknowledge the limitations of these approaches. Randomization helps distribute order effects across conditions but does not eliminate the potential for cumulative effects. Breaks may vary in effectiveness among participants, and fatigue effects could still accumulate over the entire experimental session. The overall length of our sessions, while necessary for collecting sufficient data, may have exacerbated fatigue effects, particularly towards the end.

To address these limitations in future research, several strategies could be employed. Implementing a counterbalanced design with multiple sessions could help separate the effects of trustworthiness from potential order and fatigue effects. Incorporating explicit measures of fatigue and attention throughout the experiment would allow accounting for these factors in the analysis. Utilizing adaptive procedures could efficiently probe the effect of facial trustworthiness on time perception while minimizing the number of trials and overall experiment duration. Exploring between-subjects designs for trustworthiness levels could eliminate carry-over effects, albeit at the cost of increased participant numbers. Finally, investigating how the relationship between facial trustworthiness and time perception might change over the course of an experimental session could reveal interactions between trustworthiness effects and fatigue.

5.8. Future Research Directions

5.8.1. Investigating Different Timing Paradigms

To develop a more comprehensive understanding of the relationship between facial trustworthiness and time perception, future research should investigate this phenomenon using a variety of timing paradigms. This approach would not only validate our findings but also potentially reveal different aspects of how facial trustworthiness influences different components of temporal processing.

1. Temporal Reproduction Task: Implementing a temporal reproduction task, where participants are asked to reproduce the duration of a presented stimulus, could provide more direct measures of perceived duration. This paradigm, as used by Effron et al. (2006) in their study on embodied cognition and time perception, might reveal whether facial trustworthiness influences the internal representation of duration or the production of timed responses. The reproduction task could also help disentangle perceptual effects from decision biases that might be present in the bisection task.
2. Temporal Production Task: A temporal production task, where participants generate a specified duration, could shed light on how facial trustworthiness affects the internal pacemaker mechanism proposed in internal clock models. This paradigm might reveal whether trustworthy or untrustworthy faces modulate the speed of this internal clock, providing insights into arousal-based effects of facial trustworthiness on time perception.
3. Verbal Estimation Task: Incorporating a verbal estimation task, where participants provide numerical estimates of stimulus durations, could offer a more fine-grained measure of perceived duration. This approach, similar to that used by Gil and Droit-Volet (2011) in their study of emotional effects on time perception, might capture differences in time estimation that are not detectable with the categorical judgments of the bisection task.
4. Temporal Generalization Task: A temporal generalization task, where participants judge whether presented durations match a learned standard, could provide insights into how facial trustworthiness affects the precision of temporal memory. This paradigm

might reveal whether trustworthy or untrustworthy faces influence the variability of temporal judgments, in addition to their central tendency.

5. Prospective vs. Retrospective Paradigms: Comparing prospective timing (where participants know in advance they will make time judgments) with retrospective timing (where time judgments are unexpected) could illuminate how facial trustworthiness affects attention to time and incidental temporal memory. This comparison might reveal whether the effects of facial trustworthiness on time perception are mediated by attentional processes or operate at a more implicit level.
6. Duration Discrimination Task: A duration discrimination task, where participants compare the durations of two sequentially presented stimuli, could provide a measure of temporal sensitivity. This paradigm might reveal whether facial trustworthiness affects the precision of comparative duration judgments, potentially highlighting different mechanisms than those involved in absolute duration judgments.
7. Multisensory Timing Tasks: Incorporating multisensory timing tasks, where facial stimuli are paired with auditory or tactile stimuli, could illuminate how facial trustworthiness interacts with cross-modal temporal integration. This approach might reveal whether the effects of facial trustworthiness on time perception are specific to visual processing or generalize across sensory modalities.
8. Ecological Momentary Assessment: To increase ecological validity, future research could employ ecological momentary assessment techniques, where participants make time judgments in real-world settings after brief social interactions. This approach could bridge the gap between laboratory findings and real-world experiences of time in social contexts.

By systematically investigating these diverse timing paradigms, future research can address several critical questions:

1. Are the effects of facial trustworthiness on time perception consistent across different temporal tasks, or do they manifest differently depending on the specific demands of each paradigm?
2. Do certain timing tasks reveal effects of facial trustworthiness that are not apparent in the temporal bisection paradigm?

3. How do the effects of facial trustworthiness on time perception vary across different time scales, from milliseconds to minutes or hours?
4. Are the observed effects primarily perceptual, or do they also involve changes in temporal decision-making processes?
5. How do individual differences in timing abilities interact with the effects of facial trustworthiness on time perception?

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