The Effect of Image Memorability on Time Perception and the role of Implied Motion

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PSB3E-BT15: Bachelor Thesis

Group number 40

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Month 07, 2023

Abstract

This paper investigates the effect of image memorability on time perception and it considers the role of implied motion. Research in image memorability is a relatively new subject in cognitive psychology, it has never before been researched in the context of time processing. We hypothesize that high image memorability will cause an overestimation in time and we expect implied motion to reinforce this effect. An experiment is done by means of a temporal bisection task. The experiment is a within-subjects design where fifty subjects participated, all of them recruited via SONA. The subjects estimated the duration of 154 displayed images resulting in processed data of bisection points per participant and per condition. Three participants were excluded from the data. A Repeated Measures ANOVA yielded no significant results for the main effect of image memorability and time perception (p = .096). Also for the moderating effect of implied motion is no significant difference found (p = .723). These results might be explained by the lack of power of the experiment. An additional exploratory analysis is done to explore the relation between implied motion and time perception, when not controlled for image memorability. These results suggest an overestimation of time for images with implied motion (p = .01), but this inquires further consideration. Solely on the basis of this study, we can not conclude an effect of image memorability and implied motion on time perception but it is an interesting starting point for further research.

Keywords: time perception, image memorability, implied motion

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People can perceive time differently in different situations. When doing a heavy physical exercise, a minute can feel like ages, whereas when watching a good movie, a minute feels like seconds. This illustrates the subjective nature of time. Especially when living in a world where the strictness of the clock seems to have taken over, research in time perception has become increasingly relevant. There has already been done quite some research on time perception and how it is influenced by different factors. The current study aims to investigate the effect of image memorability on time perception and it will focus on the moderating influence of images with implied motion on this effect. Understanding the effect of image memorability on time perception will provide researchers in cognitive psychology a better understanding of how image processing, memory and time perception are related. More specifically will it give an insight in human perception with regard to the concept of memorability.

When investigating time perception, the most frequently used theory in the field proposes an information-processing model (Gibbon et al., 1984). This cognitive model suggests that there is a pacemaker in the brain that transmits pulses while perceiving information for a certain period of time. The pulses go through either a gate or a switch to the accumulator. Next, the accumulator adds up all the pulses that were transmitted by the pacemaker while perceiving the stimulus. The number of generated pulses is compared to the reference memory which is based on earlier experiences of time perception. The reference memory helps to be able to accurately estimate the amount of time that has passed while perceiving the stimulus.

Both arousal and attention are thought to have an impact on how people perceive time. Arousal is assumed to influence the rate of the pacemaker, with higher arousal causing a faster rate of pulse transmission, leading to an overestimation of time (Burle & Casini, 2001; Cui et al., 2023; Treisman et al., 1990, 1992). However, the way attention affects the model is still in dispute. One theory expects attention to have an influence on the narrowing and widening of a gate between the pacemaker and the accumulator (Zakay & Block, 1997). Zakay and Block (1997) did an experiment where a non-temporal task and a temporal task were performed simultaneously in order to diminish the amount of attention paid to the temporal task. They found that when attention is focused on the temporal task, the gate will open wider so more pulses are allowed through the gate to the accumulator and time will be more precisely estimated. When attention is drawn away from the temporal task, the gate narrows and thus less pulses go through the gate, leading to an underestimation of time. Another theory states that there is a switch between the pacemaker and the accumulator which will be closed when the attention is drawn away from time and opened when the attention is focused on time (Burle & Casini, 2001; Lejeune, 1998). Both theories, either the switch or the gate model, predict an underestimation in time when the attention is drawn away from the temporal task.

Past research has established an effect of stimuli size and image complexity on time perception (Schiffman & Bobko, 1974; Thomas & Weaver, 1975; Xuan et al., 2007). While stimuli size and complexity are both related to image memorability, time perception has never before been directly linked to image memorability (Rust & Mehrpour, 2020). Image memorability is defined as the consistent memorability variation in images across different subjects (Rust & Mehrpour, 2020). When it comes to image memorability, some factors are predictors of higher memorability and other factors predict lower memorability. For example, image memorability is found to be higher for images containing people, images of atypical content and images evoking emotions such as disgust, amusement and fear (Rust and Mehrpour, 2020). On the other hand, images with nature scenes tend to be relatively less memorable (Rust and Mehrpour, 2020). Since we aim to examine the relationship of image memorability and time perception, it could be helpful to take factors into consideration that affect time perception, such as arousal (Burle & Casini, 2001; Cui et al., 2023; Treisman et al., 1990, 1992). Some research has investigated the relationship between image memorability and arousal. Images are generally better remembered when they are of high arousal (Bradley et al., 1992; Palomba et al., 1997). This illustrates a positive relationship between image memorability and arousal. Based on the temporal information-processing model mentioned above, higher arousal causes the pacemaker to transmit more pulses at a time which will lead to an overestimation of time. Thus, our hypothesis is that images with higher memorability scores will lead to an overestimation of time.

We expect implied motion in images to have a moderating influence on this effect. When movement is present in stimuli, the stimuli are recalled with greater ease than when there is no movement (Thompson, 2019). Several studies have found neurobiological evidence indicating that similar brain areas are activated when perceiving real movement and implied movement (David & Senior, 2000; Kourtzi & Kanwisher, 2000; Winawer et al., 2008). Consequently, real movement is comparable to implied motion. Based on this information combined with the study by Thompson (2019), we can to some extent presume that implied motion is related to image memorability. This idea is also supported by other studies postulating a significant difference in memorability for still images and images with implied motion (Basavaraju & Sur, 2020; Matthews et al., 2007). This suggests a positive correlation between implied motion and image memorability. Motion cues in images are proven to be a predictor for high image memorability (Basavaraju et al., 2018). An explanation for moving images to be better recognized and remembered compared to static images is that motion is the standard for visual stimuli (Matthews et al., 2007).

Implied motion is not only connected to image memorability but there is also some research done on the relation between implied motion and time perception. Nather and Bueno

(2012) focussed on the effect of images implying body movements on time perception. They found that images with implied body movements are overestimated in time due to an increase of arousal (Nather & Bueno, 2012). There has never been such a study concerning time perception and implied motion that was not specifically limited to body motion. In the present study, we aim to further explore this relationship of general implied motion and time perception. To study factors influencing time perception, we are focussing on the mechanisms affecting time perception according to the temporal information-processing model of Gibbon et al. (1984), such as arousal. Research has shown that higher implied motion is related to higher arousal (Nather et al., 2011). This could be explained from an evolutionary perspective. Noticing a moving object in the environment is crucial because of survival instincts such as looking out for predators and danger (Thompson, 2019). Survival processing, i.e., the brief assessment of important information in a threatening situation which also includes time and memory processes (Nairne & Pandeirada, 2016), is essential in such potential dangerous situations. Potential danger in an environment is thought to elicit one's arousal (Baddeley, 1972). This can be explained by the fight-or-flight response. The automatic response helps to effectively and rapidly react in threatening situations and is connected with arousing bodily reactions like the release of hormones and changes in blood pressure (Nairne & Pandeirada, 2016). Thus, potential danger in a moving environment might underly the connection between implied motion and arousal.

Based on the existing literature on memorability, we expect higher image memorability to cause an overestimation in time. This is because high memorability is related to elicited arousal and based on the temporal information-processing model of Gibbon et al. (1984) this would cause the pacemaker to generate more pulses in comparison to a non-aroused state. Since more pulses are summed up by the accumulator and compared to the reference memory, there should be an overestimation of time. Regarding the effect of implied motion, there is a positive correlation between image memorability and implied motion. Also, previous literature suggests a positive correlation between implied motion and time perception. Based on this we hypothesize implied motion to reinforce the expected effect of image memorability on time perception. Thus, because of an increase in arousal, we expect that the overestimation will be even stronger when the pictures with high image memorability contain implied motion.

Methods

Participants

After the data collection, 50 participants were recorded of which three participants were excluded from the study. A convenience sample was recruited through the first-year psychology SONA practicum pool of the University of Groningen. The subjects could sign up for time slots online through SONA and had to come to the laboratory in the Heymansbuilding of the University of Groningen at the described time. In the end, they received 1.3 credits for participation. The EC approval code of the study is PSY-2223-S-0334.

Materials

For the experiment, we made use of a bisection task where a reference point is compared to different stimuli (Kopec & Brody, 2010). The experiment is designed in OpenSesame, a free and open-source program (Mathôt et al., 2012). In total, 154 images were selected of which were 31 images containing implied motion. The majority of images were selected from the LaMem dataset which has pre-rated scores for memorability that were predicted by both human raters and algorithm predictions (Khosla et al., 2015). Because of our specific requirements for the content of the images, a part of the images was selected from the International Affective Picture System (IAPS), which is a semantically categorized database with image ratings for emotional valence and arousal (Bradley & Lang, 2017). Memorability scores were predicted using the ResMem python package that calculates memorability regression using residual networks (Needell & Bainbridge, 2022).

Procedure

To do the experiment, the participants were invited to the lab and were seated in front of a computer. The experiment took place in a lab to minimize distractions and to control for unwanted influences in order to do a reliable comparison. First, participants would fill in the consent form and then follow the directions on the screen. The researchers explained the experiment and were around to provide additional information when necessary. The experiment started with a practice phase (Figure 1). A fixation point was shown for a random duration between 1000 and 3000 milliseconds which was followed by a blue circle that was shown for either a short time interval (600 ms) or a longer time interval (1600 ms). The participants were asked to judge whether the circle was shown for the short or the long duration. They would press the ‘s’ key when they judged the duration to be the short anchor and they pressed the ‘l’ key when they judged the duration to be the long anchor. After each answer, the participants received feedback on their performance. There were ten practice trials for the participants to be able to distinguish between the long and the short anchor which were serving as a reference point for later comparison.

In the experimental phase (Figure 2), the participants were asked to compare the duration of a shown image to the long and short durations stored in their memory. A fixation point was followed by an image that was displayed for one of the seven probe durations (600 ms, 707 ms, 832 ms, 980 ms, 1154 ms, 1359 ms, 1600 ms). When participants estimated the duration to be closer to the short time interval, they pressed the ‘s’ key and when they estimated it to be closer to the long time interval, they pressed the ‘l’ key. All 154 images are shown five times randomly for one of the seven durations.

Figure 1

Graphical Depiction of the Practice Phase in the Experiment

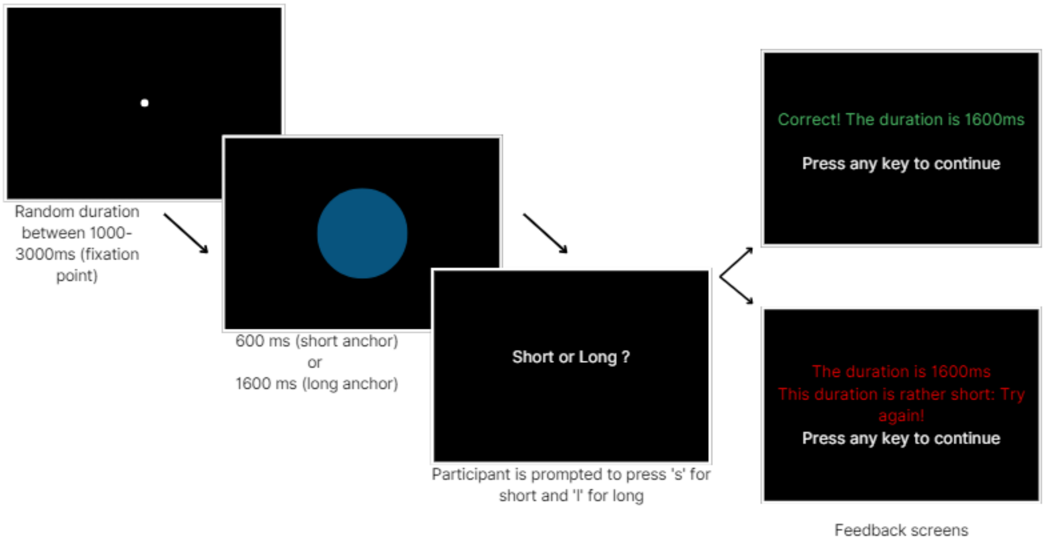
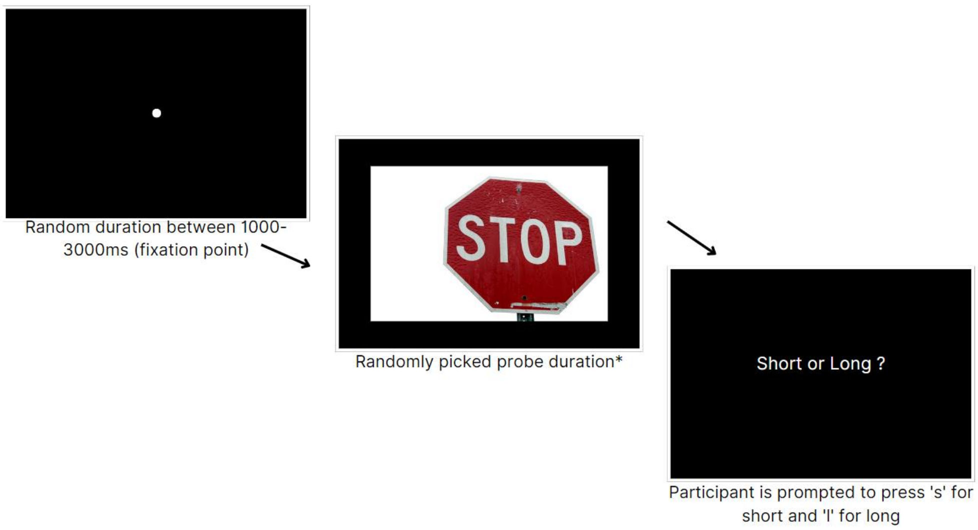


Figure 2

Graphical Depiction of the Experimental Phase in the Experiment



Data analysis

The raw data are binary responses of ‘short’ and ‘long’. Per probe duration, the probability of pressing ‘l’ is calculated for each participant. As the durations of the probes increased, the probability for a subject to respond with ‘long’ increased via a monotonic function. To this data, we fitted psychometric functions per participant in order to get bisection points, a 50% chance of responding with ‘long’. The bisection point provides a reference for how time is processed in the brain, allowing us to measure the estimated duration of stimuli and factors affecting it, such as image memorability. A lower bisection point implies an overestimation of time while a higher bisection point implies an underestimation of time. The processed data consists of separately calculated bisection points per participant and per condition.

In this experiment, the dependent variable is time perception measured by means of the bisection points. The first independent variable is image memorability with three levels: low, medium and high. The continuous memorability scores are ranging from 0 being hardly memorable to 1 being high memorable. These scores are trichotomized to be able to work with categorical predictors. High image memorability scores are categorized as scores above .79, medium memorability is defined between .59 and .79 and low image memorability level contains scores under .59. These categorizations are established on the basis of different studies relating to image memorability similar to this current study (Isola et al., 2011; Rust & Mehrpour, 2020). The second independent variable is implied motion with two levels: images with implied motion and neutral images. The statistical analyses consist of a repeated measure analysis of variance (RMANOVA) to compare the means of bisection points per condition and per image memorability level across conditions. Then we are performing an exploratory analysis containing a Paired Samples T-Test to explore a possible relationship with implied motion and time perception, when not controlled for image memorability. An α level of .05 was used for all statistical tests. The statistical analyses were conducted with JASP (v 0.15.0.0).

Results

When checking for assumptions for the main analysis, the data of neutral images in high image memorability is not normally distributed. Theoretically, this was expected since neutral images are less likely to be memorable. Though for the analysis it is not ideal because a violation of normality has consequences for the reliability of the results. Also, the assumption of sphericity has not been met because the variances of the differences over conditions are disproportionate. To account for this violation, the Greenhouse-Geisser correction is applied to all reported results.

Table 1 shows the means and standard deviations of all the separate conditions. Regarding implied motion, low image memorability has the highest average bisection point which is followed by medium image memorability while high image memorability has the lowest average bisection point. For the neutral images, a similar pattern is seen with the highest average bisection point being for low image memorability.

Table 1

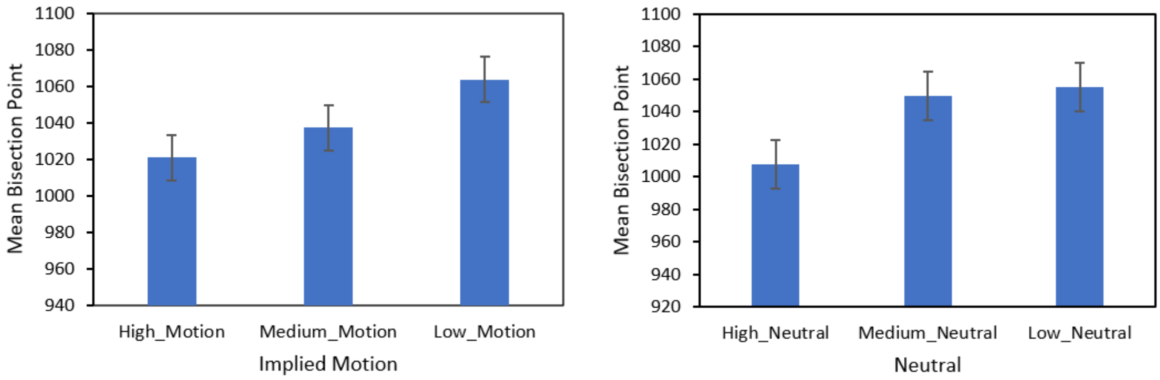
Means (and Standard Deviations) of Bisection Points per Condition & Memorability Level

Condition	Memorability Level		
	High	Medium	Low
Implied Motion	1020.823 (131.714)	1037.217 (133.146)	1063.648 (223.663)
Neutral	1007.452 (206.421)	1049.469 (117.638)	1055.103 (131.690)

The first hypothesis expects an overestimation in time for images with higher memorability. When testing this hypothesis, the RM ANOVA yielded no significant difference between the different levels of memorability on time perception ($F(44, 1.687) = 2.527$, $p = .096$, MSE = 22547.996, $\eta^2 = .027$). The second hypothesis expects images with implied motion to strengthen the effect of the first hypothesis. But when taking implied motion and image memorability both into consideration, there is also a nonsignificant difference in time estimation found ($F(44, 1.764) = 0.288$, $p = .723$, MSE = 14645.857, $\eta^2 = .002$). The means of the bisection points are visually displayed in Figure 3.

Figure 3

Means of the Bisection Points per Condition



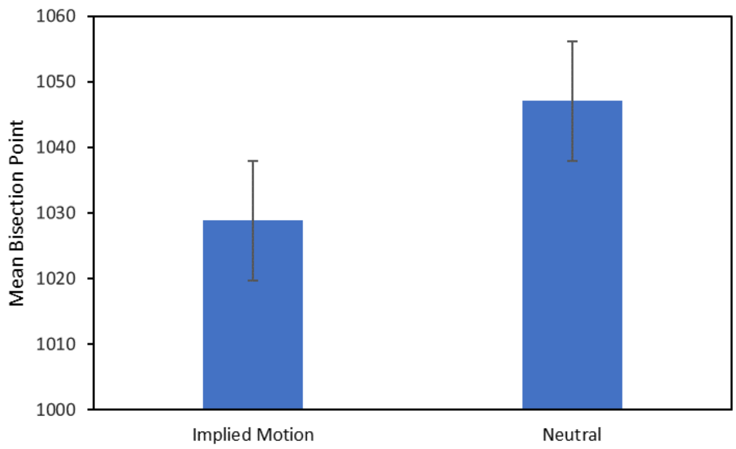
Note. The error bars are representing the standard errors.

Exploratory Analysis

For exploratory purposes, a Paired Samples T-Test between images with implied motion and neutral images on time perception is ran. The factor of image memorability is not controlled for in this exploration and this analysis was not part of the original hypotheses. Based on the exploratory analysis, there is a significant difference between images with implied motion (M = 1028.847, *SD* = 121.014) versus neutral images (*M* = 1047.036, *SD* = 119.711) on time perception ($t(47) = -2.62$, $p = .01$). The difference is visualized in Figure 4. Since there was no original hypothesis predicting the effect of implied motion on time perception, this outcome is exclusively useful for exploratory purposes which means that no direct conclusions can be derived from these findings. Important to note is that the means of the bisection points in this analysis are not directly comparable to the means of the bisection points of the previous analysis. This is because the bisection points in the exploratory analysis are calculated for implied motion across all levels of image memorability which is not the case for the previous analysis.

Figure 4

Means of the Bisection Points per Condition



Note. The error bars are representing the standard errors.

Discussion

The first hypothesis expected an overestimation of time for images with higher memorability. Although the data does seem to match our expectations, the differences are not big enough to generate a significant result. The second hypothesis states that higher implied motion is expected to reinforce the effect of the first hypothesis. Also for this hypothesis, no significant effects are found.

There are several possible explanations for these findings. The nonsignificant results could be attributed to an insufficient amount of power. Low power decreases the probability to find significant results. The effect size for the analyses seems to be very small which could also explain the low power. It is highly plausible that a lack of power is the underlying explanation for our nonsignificant findings because, at least for the first hypothesis, we do see a pattern in the data that follows our prediction. With a higher power, maybe the results would have been closer to our expectations.

Also, there is a possible theoretical explanation for our results. Time perception is influenced by both arousal and attention (Burle & Casini, 2001; Zakay & Block, 1997). In the current study, we mainly focused on the role of arousal on the temporal information-processing model to build our hypothesis. We might have neglected the effect of attention in this process. Literature suggests that there would be an underestimation of time when the attention is drawn away from the temporal task due to either a switch or a gate that keeps the transmitted pulses from going to the accumulator (Burle & Casini, 2001; Lejeune, 1998; Zakay & Block, 1997). This theory is based on experiments with dual task performances, namely, a temporal task in combination with a nontemporal task. This is not the case for our experiment, since we only worked with one single task that was temporal. Maybe the mechanism of attention has still played a role in our experiment and it might have affected the outcomes, but we did not control for this situation. It could be possible that attention has had an effect on the over- or underestimation of time that may have undermined the overestimating effect of arousal. A suggestion for future research is to include and investigate the effect of attention on time perception. For example, this could be done by including a non-temporal task besides the temporal task to control for the effect of attention.

This is the first study to combine the only recently researched phenomenon of image memorability with time perception and it serves as a starting point for future research around this subject. The effect of implied motion gives an interesting turn on the results since the exploratory analysis indicates a possible significant effect of implied motion on time perception. The overall effect is not found but this could also be due to low power and several limiting factors in the experiment.

One of the limitations could be the effect of tiredness. The entire experiment took about 50 minutes, which is a long time for the participants to concentrate. When subjects are getting tired towards the end of the experiment, they might be answering less accurately and attentively than they were at the start. This might have influenced the results. But although the experiment was time consuming, we do not expect the aspect of tiredness to have had a very noticeable impact on the outcomes since the task of our experiment was easy doable in terms of cognitive load. It did not require a lot of mentally tiring reasoning.

Another limitation is the distribution of the data. The obtained data was imbalanced, which is an impediment to the analysis. Images with high implied motion are overall more likely to be high in memorability which means that there are less images with implied motion that are low in memorability, resulting in imbalanced data. The opposite applies to neutral images because they are more likely to be of lower memorability. This imbalance caused a violation of the assumptions of sphericity and normality which may have led to incredible results. An attempt to fix the imbalanced data is implemented by transforming the data. This corrected the data to some extent and minimised the imbalance. A negative consequence of the transformation is that a considerable part of detail from the data is lost which might have added to the lack of power in the experiment.

Another point of discussion is the generalizability of the used image memorability scores. The memorability scores of the images are adopted from pre-rated datasets. This means that the memorability scores are based on a different sample than it is applied to in this experiment. We did not base our memorability scores specifically on our sample size which means that the estimated memorability scores may deviate from the actual memorability scores for this group of participants.

Lastly, there is a limitation concerning the used stimuli. There are a lot of possible confounding factors since the used images are very variating in shape, complexity and content. It is hard to control for additional factors. Different image properties could have had different effects on the processing of information which means there is probably a substantial amount of statistical noise within the data.

Besides the analysis for the original hypotheses, there is also done an additional exploratory analysis. This analysis regards the effect of images with implied motion on time estimation, when not controlled for image memorability. This analysis indicates a significant difference between images with implied motion and neutral images. Images with implied motion would cause an overestimation of time according to the exploratory analysis. This analysis was not part of the original hypotheses and there can not be drawn any direct conclusions from these outcomes. A similar study of Nather and Bueno (2012) investigated the effects of images with bodily movements on time perception where they found an overestimating effect of time. There has never been a study concerning time perception and implied motion that was not specifically limited to body motion. Our significant results of the explanatory analysis provides good reason to further study the effect of general images with implied motion on time perception.

In conclusion, we found no significant main effect of image memorability on time perception. There is a trend to be seen that is in line with the hypothesis that high image memorability leads to an overestimation of time as indicated by a lower average bisection point. Regarding implied motion, there is not a moderating effect found in the relation between image memorability and time perception. A possible explanation for these findings could be the lack of power. For future research on this topic, we suggest using a large sample to increase the statistical power. Also, we advise to control for the possible effect of attention on time perception. A way to do this could be to add a nontemporal task besides the temporal task to be able to regulate the attention focused on the temporal task. Additionally, an exploratory analysis is done founding a positive effect of implied motion on time estimation. This is an interesting motive for further investigation of this topic. Overall, the current study is a valuable starting point for broader knowledge within the subject of time perception in the context of image memorability and implied motion.

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