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The Illusion of Seconds: Human Time Perception in the Collaborative Game "The Mind"

Bachelor's Project Thesis

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Abstract: Time perception plays a crucial role in social interaction and falls subject to the scalar property of time, which states that variability in perception increases with interval duration. This plays a large role in the collaborative game The Mind, in which players work together to play their cards in ascending order, without revealing them or taking turns. In order to successfully complete the game, players need to coordinate their timing of playing cards. An experiment was designed in order to investigate human time perception in the game of The Mind. Twenty-three participants played six games of The Mind against a computer. After playing a card, they were asked to estimate how much time has passed since the previous card was played. Results suggest that larger gaps between the cards and higher anxiety experienced by participants negatively affect the accuracy of time estimation.

1 Introduction

As Hallez & Droit-Volet (2018) put it, "time processing lies at the core of the social interaction". During the COVID-19 pandemic, many conversations had to switch to an online setting. One irritating feature of remote communication is the difficulty to time one's utterance. Conversations might be distorted by connectivity issues or transmission delays. Moreover, Boland et al. (2022) found that delaying the transmission disrupts the natural rhythm of a conversation and delays turn-taking times by more than the duration of a transmission delay, while also reducing the number of turns being taken. Because of a delay in hearing the other speaker, participants could not accurately predict when they should start their own utterance. This real-life example shows the importance of timing for human cognition.

In the collaborative game The Mind, the importance of timing cooperation becomes explicit. It is a game in which cooperation "relies on your sense of time" (Warsch, 2018, p. 2). The game challenges the players to attempt to achieve a common time perception.

The Mind is a card game played with 2 to 4 players. The deck consists of 100 cards, each with its unique number (ranging from 1 to 100), that are shuffled before the beginning of the game. In every round, players have to play their cards in ascending order, without taking turns or disclosing their cards to each other. For example, if there are two players holding one card each, and the first player has card 24, while the second player holds card 16, the second player should play their card first for the players to successfully complete the round. However, as the players do not know each other's cards, the decision on when to play the card is based purely on estimation. The original game also includes other components, such as levels, lives and throwing stars, but they are omitted in the above description as this research will only use the basic structure of the game.

A reasonable strategy to play the game is to make one's waiting time dependent on the difference in number between the current card in the middle and the card they want to play. This allows the other player time to play their card, if necessary. Theuwissen (2022) reported that this strategy was a predominant strategy among participants of their study. They also found that human data validated the results of a cognitive model that implemented this strategy.

The strategy, however, is subject to the scalar property of time perception. According to this property, variability in perception increases proportionally to the duration of the perceived interval (Matell & Meck, 2000). The longer the interval, the less accurate estimating its duration is. The property is explained by Weber's law, which holds that stimulus sensitivity is proportional to stimulus intensity and has been found to be the best explanation of variability in time perception, compared to other models (Haigh et al., 2021). The same property has also been found in animal time perception (Gibbon, 1977).

In The Mind, players tend to decide to play their card by estimating the time interval that has elapsed since the last move, and matching that time interval to the increment between the two cards. Therefore, their decision significantly relies on how they perceive time. The goal of this research is to investigate how well the subjective time perception corresponds to the objective passage of time during strategic interaction in the game The Mind. The expectation is that the greater the gap between the current card and the card to be played is, the less accurate the estimation of the interval will be. Moreover, time perception may be influenced by the participant's state of mind or other factors in the game.

In this paper, an experiment measuring human time perception in the game The Mind will be described. Human participants played against a computer. Throughout the game, they were asked to estimate a time interval that had passed between the card they played and the previous played card. First, a short summary of how humans perceive time will be introduced. In the methods section, the implementation of the experiment will be explained. In the results section, the data from the experiment will be presented and analyzed. Finally, in the discussion section, the conclusions drawn from the research, its potential problems, and possible future directions will be discussed.

2 Human time perception

The ability to perceive time is crucial for human cognition. Humans need to estimate time durations in all sorts of everyday situations, from crossing a street to learning how much it takes before a pressed button reacts. In this section, different models of timing will be discussed and several factors influencing human time perception will be described.

In order to play The Mind, players need to have some sort of internal clock that would allow them to measure the passage of time. Different internal clock models have been developed in time perception research. All such models must consist of three components: a clock component, counting the current interval; a memory component, storing previous interval estimations; and a decision component, that compares the current estimations to the previous ones, based on context (Matell & Meck, 2000). For example, Theuwissen (2022) describes a cognitive model capable of playing The Mind. Every time a card is played, a new time experience is saved in the memory. When a new interval estimation is made, it is based on the aggregated pool of experiences.

Matthews & Meck (2016) describe three general conceptualizations of timing: pacemaker-accumulator models, oscillator models, and sequential-sampling models. The first type of models consists of a pacemaker generating pulses and an accumulator that counts them. Oscillator models posit the existence of neural oscillators with different periods that allow for encoding time duration. In short, an interval can be encoded by checking which oscillators were active when the interval ended. Sequential-sampling models derive from drift diffusion models of decision-making, which assume that information driving the decision-making process is sampled from the percept. Sampling continues until the accumulated information reaches a certain threshold. All models, however, should be able to account for the scalar property of time perception (Haigh et al., 2021).

The duration of the interval, described by the scalar property of time perception, is not the only factor affecting how humans estimate time intervals. Time perception falls subject to many illusions (Eagleman, 2008). Events that are more complex in structure are judged to last longer. Brighter, larger, more numerous stimulus deceives the brain that perceives it as having a longer duration. Familiar or predictable stimulus, such as a number in a sequence of repeating numbers, is also judged as lasting shorter than odd or unexpected stimulus. What Eagleman points out as well is that "time is not one thing" (p. 133). When one temporal judgment changes, other related judgments do not necessarily have to. For example, an overestimation of a stimulus duration does not always affect the perceived flicker rate of that stimulus.

Another intriguing factor playing a role in time perception is social interaction. How humans perceive time in interactions with others depends on how developed their theory of mind is. Theory of mind is the ability to understand and infer mental states of other people that children may start to develop as early as at the age of 2 (Carlson et al., 2013). Hallez & Droit-Volet (2018) found that children with explicit theory of mind produced more distorted time estimations when having to assess the duration of human silhouettes appearing on the screen. The silhouettes represented different individual states such as aging, movement, emotion, or movement with an object. Children with explicit theory of mind would embody the state of a silhouette better, and, for example, produce shorter durations for a running man than for a walking man. It is known that observing emotion affects time perception (Li & Yuen, 2015). Similarly, feeling emotion affects how humans perceive time (Gable et al., 2022).

It can be therefore seen that human time perception is influenced by a multitude of factors. This research aims to further the understanding of how humans perceive time in a collaborative game setting.

3 Methods

An experiment was conducted in order to gather data about human gameplay and time perception during the game of The Mind. Participants played six games of The Mind against a computer. For every game, the computer always followed the same predefined strategy across all participants. Most of the time, the computer followed the strategy described by Theuwissen (2022): it waited the number of seconds corresponding to the gap between the current card in the middle and the card it has to play. However, unlike the cognitive model designed by Theuwissen (2022), the computer always followed a strict protocol, playing its cards with millisecond accuracy. If the current card changed in the meantime (as a result of the participant playing their card), the computer would reset its counter, and wait for the number of seconds representing the new gap between its own card and the new current card. There were a few exceptions to that strategy used by the computer, which will be explained in detail in Section 3.2.

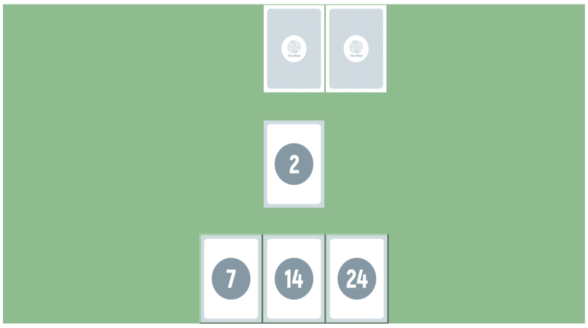

Figure 3.1: The interface of the game during game (1). The participant can see their three cards. The computer has already played its first card, which can be seen in the middle.

3.1 Stimuli

Six games were designed for the participants to play. In every game, both players (the computer and the participant) received 3 cards each (see Figure 3.1).

The cards received by the computer and the participant in the six games were:

1. Computer's cards: 2, 20, 49
   Participant's cards: 7, 14, 24

2. Computer's cards: 25, 35, 85
   Participant's cards: 10, 55, 70

3. Computer's cards: 20, 50, 100
   Participant's cards: 44, 72, 98

4. Computer's cards: 3, 54, 67
   Participant's cards: 50, 65, 97

5. Computer's cards: 20, 70, 75
   Participant's cards: 4, 29, 63

6. Computer's cards: 70, 85, 90
   Participant's cards: 3, 17, 45

The games were designed primarily to investigate how the size of the gap between the cards affects time perception. Games (1), (5), and (6) contain small gaps, below 10, from the perspective of the participant. Games (2), (3), (4), and (6) contain gaps from 10 to 30. Gaps greater than 30 are present in games (4) and (5). Following Weber's law, participants are expected to be less accurate in their estimations as the gap between the cards, and therefore the participants' waiting time, increases (Haigh et al., 2021; Theuwissen, 2022).

In half of the games, the participant possesses the lowest card, and should therefore start the game. Among all games, there are 6 instances when the participant plays after themselves and 9 when they follow the computer's move. Moreover, the cards played by both the computer and the participant vary from low to high numbers. This allows for possibly detecting an effect that the number of the card played can have on the participant's perception.

In the game, the computer could hold either one, two, three, or no cards, while the participant was waiting to play their card. The expectation is that the less cards the computer has, the more anxiety the player will feel, since they expect it is their turn to play the card. The design of the game allows for distinguishing three levels of anxiety: three cards – low anxiety, two cards – medium anxiety, and one card – high anxiety. No cards were excluded as a factor since when the computer had no cards, the participant could play all of their cards immediately. The prediction is that more anxious players will make more errors when estimating time intervals.

3.2 Task design

As already mentioned, before playing its card, the computer waited for the number of seconds corresponding to the gap between the card in the middle and its lowest card. To better show how the strategy of the computer worked, game (2) can be described as an example. In that game, the computer waited 25 seconds if the other player did not play their card. If they did, the computer waited 15 seconds after the first card of the participant was played. Then it waited 10 seconds to play its second card. After the participant played "55", the computer waited 30 seconds, or, if they played "70" afterward, it played its last card immediately after the last card of the participant was played. In general, the computer always waited the number of seconds corresponding to the gap between the cards. If the situation changed in the meantime, the waiting time was recalculated and the elapsed time was set to 0. This implementation allowed the participant to feel that they are truly playing a game and that there exists a possibility of making a mistake.

The exceptions to the strategy used by the computer were as follows: in game (1), the computer always played "2" after 0.7 seconds from the beginning of the game and waited for the participant to play "14" to then wait 6 seconds before playing "20". This special case was implemented in order to ensure that the participants will have enough time to play their first two cards uninterrupted, and that they will not play them before the computer plays its lowest card. The participant had to play two cards one after another, and the gap between them, and between them and the next card of the computer, was quite small. In game (3), the computer waited indefinitely for the participant to play "98" in order to play its last card, "100". This was a reasonable design decision, as a rational agent, that the computer was mimicking, would notice they have the highest card possible, and that they should wait for the opponent to play all their cards, as these must be lower. Lastly, it must be noted that whenever the player's hand became empty, but the computer still possessed cards, the computer would play their cards immediately, one after another in ascending order, as there was no possibility for the participant to have a lower card.

Game (1) was always the first game for all participants. This game was quite simple, with the computer starting the game, and the participants having a lot of time to play their first two cards, and then the third card. With game (1) always being the first game, participants had a chance to establish an understanding of how the computer plays its cards. The five other games were played in random order.

The task the participants had to perform while playing the game was to estimate the elapsed time interval while observing whether the computer is making any moves. Following classification by Zakay & Block (1997), the task can be classified according to several criteria. Since the period in which they have to make an estimation is filled with a *non-temporal* task, we can call it *non-empty*. Moreover, the duration is estimated *by production*; participants decide how long they should wait, and then they produce an interval of the desired length. The estimation is *prospective*, as participants are aware they have to estimate the length of an interval before it starts.

3.3 Participants

The sample consisted of 23 participants that were recruited through the network of the researcher. The age of participants ranged from 20 to 23 years ($M = 21.26$). All participants were students at the University of Groningen and were able to understand written instructions in English. Participants signed the informed consent and stated how old they are before participating in the experiment. Participants did not receive a reward for participation.

3.4 Procedure

All participants did the task in a quiet environment, accompanied by the researcher that ensured they understood the task. Participants played the game on a computer. The program running the game was automatically collecting and saving all necessary data. The task started with an explanation of the rules. Participants were informed that they will play against a computer, but were not told the computer's strategy. The explanation was followed by a trial game. In the trial game, both the participant and the computer received one card each; for the participant, it was "5", while for the computer it was "20". The participant should have played their card first, then the computer would immediately play its card. Since the gap between the cards was quite large, participants would not get much information about what the computer would do, and there was a high chance they would successfully complete the trial game by playing their card first.

During the experiment, every time participants played a card, the game paused, and the question appeared on the screen: "How much time [in seconds] has passed before you played your card, since the previous card was played?". Participants were then able to type in their answer using the keyboard. This question was chosen as it does not explicitly point to *perception* and does not encourage participants to think about their own perception of the time interval.

If a mistake was made, the correct configuration of moves was displayed. If a participant tried to play their card too early, a text box notifying them about it appeared, and the computer's card was played. The card that the participant intended to play initially was not played, so that the participant had a chance to decide again when they should play their card. If a participant waited too long, and the computer played their card instead, a text box would appear as well, and the card would disappear from the participant's hand.

The data of the participants and their gameplay were collected for later analysis. The data included participants' age, the order of the games they played, how much time has elapsed between the last played card and their card, answers to questions (estimated elapsed time), the previous current cards, the played cards, and the gaps between them, and the cards of participants and of the computer after the move was made.

4 Results

4.1 Data preprocessing

Following Hallez & Droit-Volet (2018), for every estimation, the temporal error and the temporal standard error (TSE) were computed. The temporal error was a signed difference between the estimated and elapsed time. If an interval was underestimated, the difference was negative, if it was overestimated, the difference was positive. The temporal standard error was the temporal error divided by the time elapsed (see Equation 4.1).

$$\text{TSE} = \frac{\text{estimated duration} - \text{elapsed duration}}{\text{elapsed duration}} \tag{4.1}$$

The closer the TSE was to 0, the better the estimation was.

Temporal SE was then used to exclude certain data points from the set. Data points with TSE higher than 3 with time estimated higher than 1 were excluded. There were 12 such data points (see Table A1 in the Appendix). The threshold of 3 was chosen since for that threshold to be reached, a participant would have to highly overestimate a very short interval. For example, one of the participants

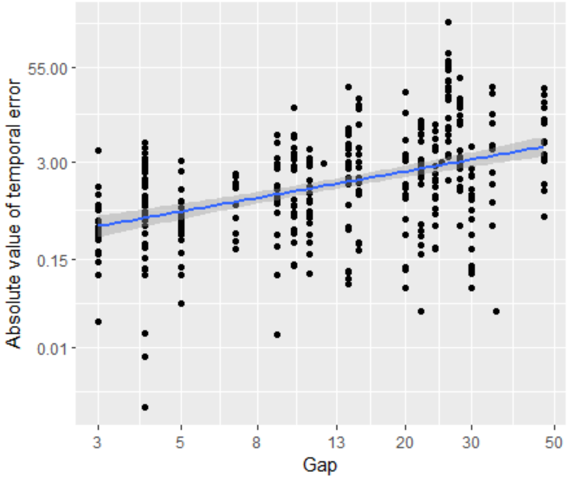

Figure 4.1: Absolute value of temporal error plotted against gap size. Both variables are log-transformed.

estimated an interval of 2.09s as 10s, which resulted in the temporal SE of 3.8. Such estimations were given most likely as the participants did not notice the last card being played and made an estimation based on the second last card. As these estimations were likely made based on the wrong card, they were excluded from the data set.

The data points for when a participant made a mistake and did not play their card before the computer were also excluded. There were 40 such data points. Lastly, one data point was excluded as the participant did not input the time estimation. In total, 53 data points were excluded (out of 414).

For four of the data points, the value of 0 was given as the answer to the question. For these data points, that value was replaced with the value of 0.01 to allow for logarithmic transformation in linear regressions, since, when log-transformed, the value of 0 results in $-\infty$.

4.2 Gap and temporal error

The prediction was that the greater the gap between the current card and the card to be played is, the less precise the estimation of the interval will be. A linear regression was run in order to examine how the gap size influenced the participants' time perception. Linear regression is used to predict the value of the dependent variable based on one or more independent variables. In this case, the dependent variable was the log-transformed absolute value of temporal error, while the independent variable was the log-transformed value of gap size.

The linear regression showed that the absolute value of temporal error can be predicted by Equation 4.2:

$$\ln|\text{error}| = 0.89 \cdot \ln(\text{gap}) - 1.87 \tag{4.2}$$

Gap size significantly predicted the absolute value of temporal error ($F(1, 359) = 80.99$, $p < .001$). However, the regression model explained only a small proportion of variance in the absolute value of temporal error ($R^2 = .18$). Figure 4.1 shows the log-transformed absolute value of temporal error for different log-transformed values of gap size. The absolute value of temporal error increases with gap size, which is in line with Weber's law.

4.3 Gap, anxiety and temporal error

As mentioned before, there were three levels of anxiety the participants could experience, related to the number of cards of the computer. The prediction is that anxiety, along with gap size, affects time perception; the higher the anxiety, and the larger the gap size, the worse estimations are given by the participants.

A linear regression was run in order to examine how the gap size and anxiety level influenced the participants' time perception. The dependent variable was the log-transformed absolute value of temporal error, while the independent variables were the interaction between log-transformed reaction time and log-transformed gap size, and the interaction between the number of cards of the computer and log-transformed gap size. The linear regression was performed with omitting the estimations for which the number of cards of the computer was 0. When the computer had no cards, the participant would not have to wait with playing their card, so the gap size did not matter. The linear regression showed that the absolute value of temporal error

Table 4.1: Estimates and p-values of all the individual coefficients of the regression model from Section 4.3.

Coefficient	Estimate	p-value
intercept	0.32701	0.56115
ln (time elapsed)	0.62391	0.01157
ln (gap)	−0.59165	0.00667
two cards computer	−1.29076	0.02488
three cards computer	−1.61530	0.00435
ln (time elapsed) : ln (gap)	0.12761	0.11810
ln (gap) : two cards computer	0.41223	0.04853
ln (gap) : three cards computer	0.50589	0.02040

can be predicted by Equation 4.3:

$$\begin{aligned} \ln|\text{error}| = 0.33 + 0.62 \cdot \ln(\text{time elapsed}) \\ -0.59 \cdot \ln(\text{gap}) - 1.29 \cdot (\text{two cards computer}) \\ -1.62 \cdot (\text{three cards computer}) \\ +0.41 \cdot \ln(\text{gap}) \cdot (\text{two cards computer}) \\ +0.51 \cdot \ln(\text{gap}) \cdot (\text{three cards computer}) \end{aligned} \tag{4.3}$$

In Equation 4.3, only the coefficients with significant p-values ($p < 0.05$) were presented. All coefficients, their estimates, and p-values can be found in Table 4.1.

The regression model explained a large proportion of variance in the absolute value of temporal error ($R^2 = .57$, $F(7, 329) = 62.9$, $p < .001$). The results show that given the same time elapsed and the same gap size, participants were more accurate in their estimations of time elapsed when the computer held more cards (and the anxiety level was lower).

4.4 Gap and time elapsed

Theuwissen (2022) found a linear relation between gap and waiting time. A linear regression was run to find the best fitting line describing the relation between these two variables in the data. The dependent variable was log-transformed time elapsed and the independent variable was log-transformed gap size. The linear regression showed that the value of time elapsed can be predicted by Equation 4.4:

$$\ln(\text{time elapsed}) = 0.89 \cdot \ln(\text{gap}) - 0.49 \tag{4.4}$$

Gap size significantly predicted time elapsed ($F(1, 359) = 160.2$, $p < .001$), but the regression model explained only a small proportion of variance in the value of time elapsed ($R^2 = .31$). However, based on Figure 4.2 that shows log-transformed values of time elapsed for different log-transformed values of gap size, it can be confirmed that the relation between the two variables is approximately linear.

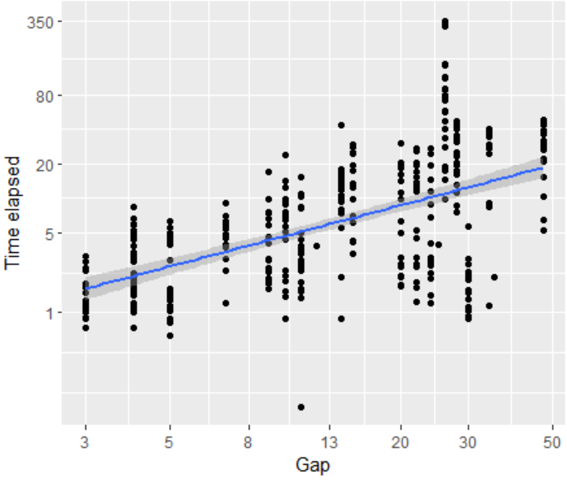

Figure 4.2: Time elapsed plotted against gap size. Both variables are log-transformed.

4.5 Lower vs. higher numbers

The cards used in the experiment varied from low to high numbers. It was therefore investigated whether a number of the card has an effect on time perception.

Two-tailed t-tests for five gap variants were run. Every t-test compared absolute values of temporal errors for two pairs of cards with different numbers

Table 4.2: Summary of the t-tests comparing the absolute value of temporal error and time elapsed for low and high numbers. All p-values are shown for the two-tailed versions.

Gap	Cards		t-test (|error|)				t-test (time elapsed)			
			t	df	p	higher for	t	df	p	higher for
4	0, 4	20, 24	-4.27	18	<0.001	20, 24	-2.66	18	0.02	20, 24
10/11	0, 10	54, 65	1.56	18	0.14	-	1.5	18	0.15	-
14/15	3, 17	55, 70	-0.38	17	0.71	-	-0.22	17	0.83	-
20/22	35, 55	50, 72	0.18	16	0.86	-	-0.9	16	0.38	-
26/28	72, 98	17, 45	3.63	20	0.002	72, 98	3.44	20	0.003	72, 98

but with similar gap size. Only pairs of cards in which no card was played as the last card in the game were considered, as in such cases the participants did not have to wait to play their card.

The first two-tailed t-test compared the gap of 4 for cards 0 and 4 (game (5)), and 20 and 24 (game (1)). The t-test showed a significant difference between the absolute values of temporal error for the two pairs of cards ($t(18) = -4.27$, $p < .001$). An additional one-tailed t-test was run. It was found that the mean absolute value of temporal error was significantly lower for cards 0 and 4 ($p < .001$). Finally, a one-tailed t-test comparing time elapsed for both gaps was run. The mean time elapsed was found to be significantly lower for cards 0 and 4 than for cards 20 and 24 ($t(18) = -2.66$, $p = .007$).

The second two-tailed t-test compared the gaps of 10 and 11 for cards 0 and 10 (game (2)), and 54 and 65 (game (4)). The t-test did not show a significant difference between the absolute values of temporal error for the two pairs of cards ($t(18) = 1.56$, $p = .14$). An additional two-tailed t-test comparing time elapsed for both gaps was run. The mean time elapsed was not found to be significantly different between the pairs of cards ($t(18) = 1.5$, $p = .15$).

The third two-tailed t-test compared the gaps of 14 and 15 for cards 3 and 17 (game (6)), and 55 and 70 (game (2)). The t-test did not show a significant difference between the absolute values of temporal error for the two pairs of cards ($t(17) = -0.38$, $p = .71$). An additional two-tailed t-test comparing time elapsed for both gaps was run. The mean time elapsed was not found to be significantly different between the pairs of cards ($t(17) = -0.22$, $p = .83$).

The fourth two-tailed t-test compared the gaps of 20 and 22 for cards 35 and 55 (game (2)), and 50 and 72 (game (3)). The t-test did not show a significant difference between the absolute values of temporal error for the two pairs of cards ($t(16) = 0.18$, $p = .86$). An additional two-tailed t-test comparing time elapsed for both gaps was run. The mean time elapsed was not found to be significantly different between the pairs of cards ($t(16) = -0.9$, $p = .38$).

The fifth two-tailed t-test compared the gaps of 26 and 28 for cards 72 and 98 (game (3)), and 17 and 45 (game (6)). The t-test showed a significant difference between the absolute values of temporal error for the two pairs of cards ($t(20) = 3.63$, $p = .002$). An additional one-tailed t-test was run. It was found that the mean absolute value of temporal error was significantly higher for cards 72 and 98 ($p < .001$). Finally, a one-tailed t-test comparing time elapsed for both gaps was run. The mean time elapsed was found to be significantly higher for cards 72 and 98 than for cards 17 and 45 ($t(20) = 3.44$, $p = .001$).

In general, it can be seen that a significant difference in mean absolute values of temporal error correlates with a significant difference in mean time elapsed. For the second, third, and fourth comparison, both differences were found to be insignificant. For the first and fifth comparison, both were found to be significant. Moreover, when both differences were significant, the higher value of time elapsed would correlate with the higher absolute value of temporal error. In the first comparison, time elapsed and absolute value of temporal error were lower for cards 0 and 4. In the fifth comparison, time elapsed and absolute value of temporal error were higher for cards 72 and 98. The summary of all t-tests can be found in Table 4.2.

It is also worth noticing that the two significant results are, in a way, “special”. The gap between “20” and “24” occurred in game (1), which was the first game for all participants. The gap between “72” and “98” was special since when the participant was waiting to play “98”, the computer would wait indefinitely, as its card was “100”. The participants’ anxiety was increasing the longer they waited, and the longer the computer would not make any move. That aligns with the previous findings, that anxiety influences the accuracy of time perception.

The experiment provides no evidence that the number of the card influences temporal error. For significant differences, higher temporal error always correlated with a higher value of time elapsed, which aligns with the scalar property of time perception.

5 Discussion

This research aimed to explore the degree of alignment between subjective perception and factual passage of time in the game of The Mind. Several predictions were made about different factors potentially influencing how people perceive time during the game. Firstly, it was predicted that the larger the gap size between the card played by the participant and the previous card in the middle was, the less accurate the estimation of time elapsed between playing the two cards given by the participant would be. Secondly, it was expected that the lower number of cards held by the computer, leading to a higher anxiety felt by the player, would lead to a decrease in accuracy of time estimations. Thirdly, it was hypothesized that a difference in the observed stimuli itself, whether the numbers of played and previous cards were higher or lower, would affect the time perception. Lastly, it was predicted that this research would confirm previous findings, namely, that the relationship between how long the player waits to play their card, and the size of the gap between the cards, is positive and linear (Theuwissen, 2022).

The results have confirmed the previous observations and lead to new findings. The relationship between gap size and how long participants waited was again found to be positive and linear. Furthermore, the relationship between gap size and accuracy of participants’ time estimations was also determined to be positive and linear. Regarding the effect of anxiety on time perception, it appeared that the higher the level of anxiety a player experienced, caused by the lower number of cards in the opponent’s hand, the less accurate their time perception was. Lastly, it was found that whether the considered cards had lower or higher numbers did not affect the player’s time perception.

Even though most of the predicted effects have been confirmed in the statistical analysis, the study can be further improved. One main problem is that in its current state, the experiment is aiming to detect multiple effects; the effect of gap size on error, the effect of gap size on time elapsed, how low vs. high numbers affect error, the effect of the number of cards of the computer, representing the anxiety level, on error. That is possible due to the design of the experiment; the card numbers are well balanced (lower and higher numbers were used), half of the games is started by the computer and half by the participant, various gap sizes were used, and different anxiety-inducing scenarios were designed. However, that is also the disadvantage of the research; different variables might counteract and diminish each other’s effects, therefore resulting in inaccurate sizes or directions of the effects. The scope of this research did not allow for performing more experiments, each investigating one isolated variable, but that should be a direction for future research on time perception in the game of The Mind.

In the experiment, participants may have used theory of mind due to the nature of the game, but they may have used a different strategy as well. As already mentioned, developed theory of mind is a factor influencing human time perception (Hallez & Droit-Volet, 2018). An interesting extension of this research would be therefore to perform an experiment that is exactly the same in its stimuli and design, but in which participants are explicitly told to count and wait for the number of seconds corresponding to the gap between the cards before playing their card. In such a task, the participants would not need to use theory of mind in order to estimate when they should play their card. The two experiments and their results could then be compared to assess to what extent theory of mind is a factor affecting time perception in the game of The Mind.

One could also introduce more human interaction to the experiment. For example, it would be intriguing to investigate how participants would experience time if they played the game with other human players in real life. In that scenario, it can be expected that participants' time perception could be influenced by the observed emotion and body language of their opponent, as it is known that observing emotion affects time perception (Li & Yuen, 2015). The interaction with the other player could also lead participants to experiencing emotions themselves, for example, a feeling of fear or shame of playing the card at the wrong time. As it is known that experiencing emotional states has an effect on time perception, it would be an interesting direction to investigate (Gable et al., 2022).

Lastly, it could be investigated how playing against an unpredictable opponent affects one's perception of time. Implementing an experiment in which the computer does not follow a predefined strategy and instead makes random choices would result in the participant experiencing unpredictable changes in stimulus. As already mentioned, the duration of unexpected stimulus is perceived differently than that of a familiar one (Eagleman, 2008). It could be therefore investigated whether an unexpected appearance of stimulus also affects the accuracy of its duration perception.

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Appendix

Table A1: The 12 data points with TSE>3 and time estimated>1 that were excluded.

ID	2	4	4	4	4	4	9	11	14	14	15	15
Age	21	21	21	21	21	21	21	20	22	22	20	20
Game #	1	2	3	3	4	4	2	1	2	5	2	5
Previous card	20	35	20	50	54	67	25	20	35	20	35	20
Played card	24	55	44	72	65	97	55	24	55	29	55	29
Gap	4	20	24	22	11	30	30	4	20	9	20	9
Time elapsed	0.44	3.96	7.47	3.97	2.07	2.09	1.67	0.18	1.99	1.91	2.49	1.24
Time estimated	11	30	30	30	20	10	20	7	11	10	11	7
Temporal error	10.56	26.04	22.53	26.03	17.93	7.91	18.33	6.82	9.01	8.09	8.51	5.76
Temporal SE	23.97	6.58	3.02	6.55	8.67	3.8	10.97	38.8	4.53	4.22	3.43	4.65
Cards participant	-	70	72, 98	98	97	-	70	-	70	63	70	63
# of cards participant	0	1	2	1	1	0	1	0	1	1	1	1
Cards computer	49	85	50, 100	100	67	-	35, 85	49	85	70, 75	85	70, 75
# of cards computer	1	1	2	1	1	0	2	1	1	2	1	2