On Time Reading Performance: A Comparison of the Clock Face and Digit Representations

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Abstract. Time plays an essential part of our lives. We are typically surrounded by two types of time representation, clock faces and digits. Previous work focused on children's ability to read time, but adults' ability to read time have received less attention especially considering recent technological paradigm shifts and altered technology usage patterns. We therefore designed a simple time reading experiment. Our results show that participants read digit representations of times more rapidly with a lower error rate than clock face representations. These patterns were also exhibited by participants who preferred clock faces. Most errors were associated with the hands at angles of 60 and 30°. Most of the participants also reported that they prefer digit representations. Implications of these results are that the choice of time representation can be an important factor in time critical context where there is a low tolerance for error.

Keywords: time representation · analog time · digital time · clock face · digit times · age factor

1 Introduction

Time is a widely used point of reference that regulates our lives in many ways. Time was traditionally represented using clock faces when timepieces were mechanical devices. It was practical to represent hours, minutes, and seconds using hands. With the emergence of mainstream computing, time became straightforward to represent using strings of digits without the need for graphics. Yet, the traditional clock face from the mechanical era has survived and is commonly used within the current graphical user interface paradigm. For instance, most smartwatches allow the user to choose if they want a traditional clock face or a digit representation.

Colloquially, clock face time representations are commonly referred to as analog time and digit representations are commonly referred to as digital time. Although practical in everyday usage, they are also somewhat misleading as a clock face in a graphical user interface is a digital representation of time – at the same degree as the digit representation is digital. From another perspective, there are also mechanical timepieces that display time using digits. There are even analog designs for sundials that show time using digits [1, 2].

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Reading clock faces involves a level of indirection where the viewer first must perceive the angles of hour- and minute hands and interpret their meaning, while digits are read directly. With practice one would expect viewers to recognize clock hand shapes and digit configurations.

Modern society comprises a diverse mix of individuals. The older segment of the population grew up without easy access to computers and therefore mostly used clock faces. The young segment of the population has been exposed to computers from an early age, and clock faces may be merely an entertaining or eccentric oddity. The number of people with a deep background clock face usage will diminish in the years to come. Based on this we designed an experiment to probe the participants proficiency in reading time. Clock reading is particularly relevant as time plays an integral part of human life. In some contexts decisions must be made rapidly and users need to read information rapidly with low tolerance for error. This study focuses on the visual presentation of time and does not address issues related to low vision [3, 4], reduced cognitive function [5], alternative modalities [6, 7], and other modes of information transfer [8].

The rest of this paper is organized as follows. The next section reviews related works while Section 3 presents the methodology. The results are presented in Section 4 followed by a discussion in Section 5. The paper is concluded in Section 6.

2 Related work

Several studies have addressed the reading of time [9]. Several of these have focused on children. Friedman and Laycock [10] found that pupils in first grade successfully were able to read digit time, while clock faces posed bigger challenges. Typically, pupils were only able to read the full hour. Their study, involving 240 participants, observed this situation up to fifth graders. Similarly, Boulton-Lewis, Wilss and Mutch [11] also found that schoolchildren found it easier to read digit times, although they did not necessarily understand the meaning of the times. They also observed that at fourth grade pupils start to develop systematic strategies for utilizing the fact that there are 60 minutes in an hour. Ali, Singh and Sandnes [12] found that school children preferred clock faces over digit representations, while adults preferred digit representations. Vacali [13] found that children found it more difficult to encode time than decode time and that this difficulty negatively correlated with age. Burny, Valcke and Desoete [14] found that pupils' ability to read time were related to their mathematics abilities. Burny, Valcke, Desoete and Van Luit [15] compared the time reading abilities of Flemish schoolchildren to Chinese schoolchildren and found that the Chinese school children's abilities were two year ahead of the Flemish schoolchildren. The authors attributed this difference to differences in the curriculum. Reading level in general is often connected to education level [16, 17, 18] and one may speculate that reading skills and mathematical skills are interrelated when solving such tasks.

On the other side of the demographic scale Bodner et al. [19] studied clock face reading and setting in elderly with dementia. They claimed that reduced clock setting abilities could be a predictor to be used when screening dementia. Along similar lines, several studies refer to clock face drawing tests [20, 21, 22]. Clock setting interfaces has also been studied in the human computer interaction domain [23, 24, 25].

The debate about the strength and weaknesses of clock faces versus digit times share similarities with the debate about pie charts versus bar graphs [26], and they are similarly relevant when such information is used in critical visualizations [27]. The renowned visualization expert makes some valuable comments about circular visualizations in the aptly titled text "Our Irresistible Fascination with All Things Circular" [28]. Many studies point out that when the reading task involves assessing part of a whole, the pie chart is more effective than other chart types [29], while if searching for the smallest or the smallest portion the bar chart is more effective than pie charts [30]. Several studies within cognitive psychology have explored the perception of angles. Xu, Chen and Kuai (31) showed that the size of the just noticeable angle depends on the angle itself, and that our sensitivity to angles is more sensitive when the angles are nearly vertical or horizontal and less sensitive around 60° (degrees). For pie charts, it is not the angle per se, but rather the area and arc lengths that is most prominent in affecting viewers' judgements [32, 33]. It has also been shown that small portions often are underestimated, and large portions are overestimated [34]. The literature has also explored other more exotic circular graphs such as radar plots [35], petal plots [36], and polar plots [37].

3 Method

3.1 Experimental design

A within groups experimental design was chosen. Time representation was the independent variable with two levels, namely clock-face and digits. Dependent variables included response time, error rate and preference. Such parameters are often used in such experiments [38, 39, 40].

3.2 Participants

A total of 16 participants were recruited with a mean age of 40.2 years (*SD* = 17.6). The youngest participant was 22 year and the oldest was 68 years. Participants were recruited using convenience sampling.

3.3 Materials

A total of 24 random times rounded to the nearest 5-minute timestamp were generated. Half of these were represented using a clock face (see Fig. 1), and the other half were represented using a digit format (see Fig. 2). Positive polarity [41] was used with maximum contrast [42, 43, 44, 45], that is black foreground on a white background to maximize legibility. The timestamps were randomized, and the sequence of clock face and digit times were presented in alternating order. The times were put into a PowerPoint presentation with one time at each slide. There was a separating page in between each time in the presentation so that each time measurement could be separated.

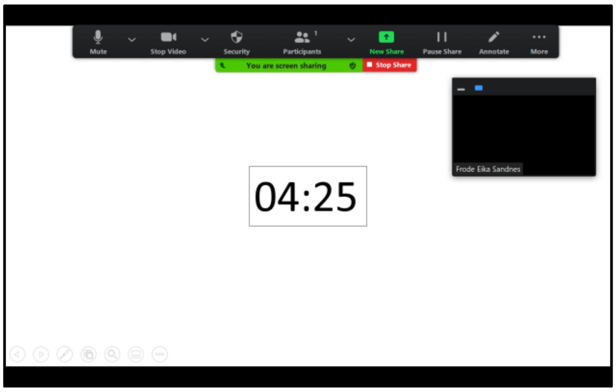

Fig. 1. Example of digit time task (viewed in zoom) used in the experiment

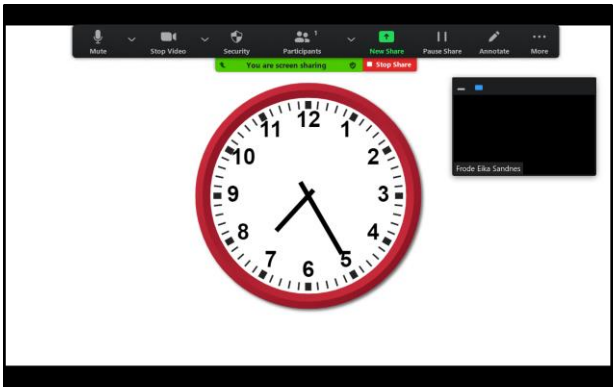

Fig. 2. Example of clock face time task (viewed in zoom) used in the experiment

3.4 Procedure

The experiment was conducted remotely using zoom (see Figs. 1 and 2). The participants were first sent the link to the zoom meeting. After connecting the participants were informed about the experiment. The PowerPoint presentation was shared with each of the participants and when shown the time, the participants were asked to read the time and speak it out aloud. The experimenters noted down the response and measured the time to provide the response using a smartphone stopwatch. After the experiment, the participants were asked complementary questions including their preferred time representation, what they typically used and their age. Participants were tested individually, and each session lasted between 15 to 20 minutes.

The experiment was conducted in single sessions and there was therefore no need to link data records across sessions [46]. The experiment could therefore be conducted anonymously.

3.5 Analysis

The mean response time for each participant per time representation type was computed as well as the error rate. The clock face types were also analyzed according to the angle of the hands. Fig. 3 shows how the angles were interpreted. Since the time representations had a minimum resolution of 5 minutes the angles where 0°, 30° and 60° (degrees). Note that 90° angles are classified as 0° for simplicity.

The responses were statistically analyzed using JASP version 0.13.1.0 [47]. Shapiro-Wilks tests showed that the observed response times and error rates were not normally distributed. Non-parametric tests, namely Wilcoxon signed-rank tests and Spearman correlations, have therefore been employed herein.

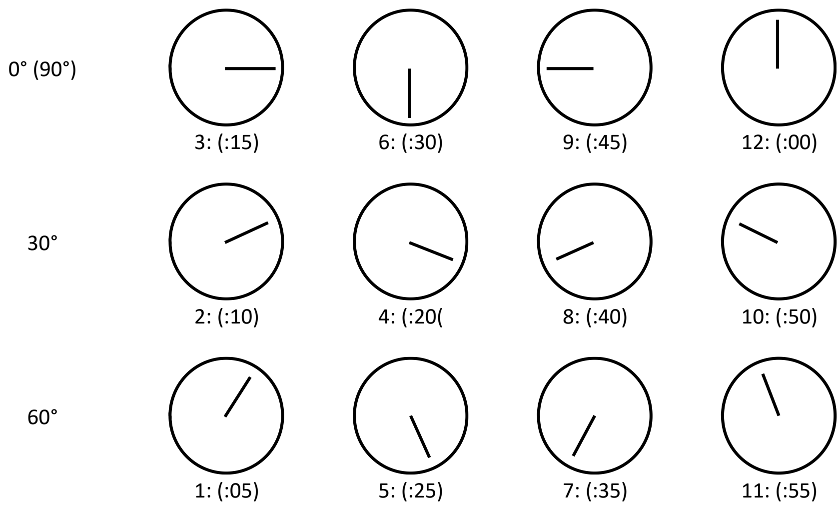

Fig. 3. Clock face hand angle interpretations for hours: (:minutes).

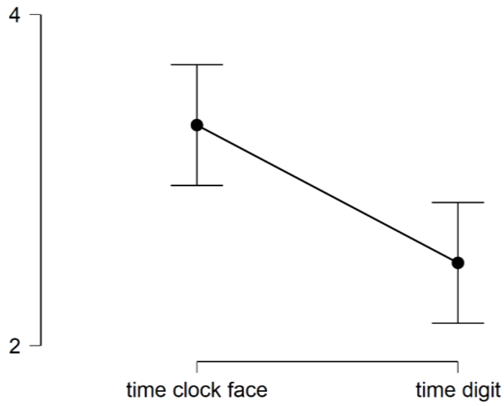

Fig. 4. Mean response times in seconds. Error bars show 95% confidence intervals.

4 Results

Fig. 4 shows that the time in seconds to read the digit time representation (*M* = 2.5, *SD* = 0.5) was shorter than the time to read the clock face representation (*M* = 3.3, *SD* = 1.3) and the difference was statistically significant (*W* = 130, $p < .001$).
We also correlated the response times for clock face against age and found a significant strong negative correlation ($r_s(16) = -0.717$, $p = .002$), that is older participants were faster at reading the clock face time than younger participants. No significant correlation was found for the digit representation ($r_s(16) = -0.364$, $p = .166$).

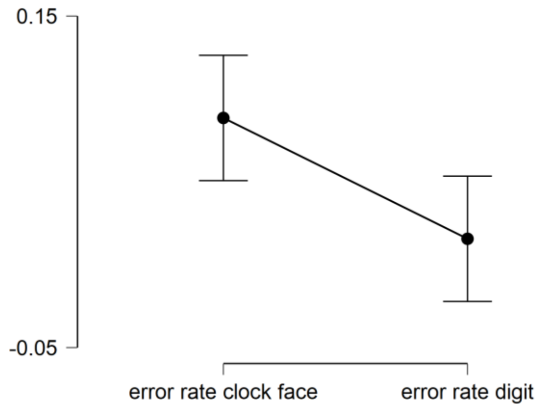

Fig. 5. Error rates. Error bars show 95% confidence intervals.

Fig. 5 shows that the error rates associated with reading the digit time representation (*M* = 1.6%, *SD* = 3.4%) was lower than the error rates associated with reading the clock face representation (*M* = 8.9%, *SD* = 10.7%) and the difference was statistically significant (*W* = 36.0, $p = .012$).

Similarly, the error rates associated with the clock face showed a significant negative correlation with age ($r_s(16) = -0.859$, $p < .001$). No significant correlation between age and error rates of the digit representation was detected ($r_s(16) = 0.296$, $p = .266$).

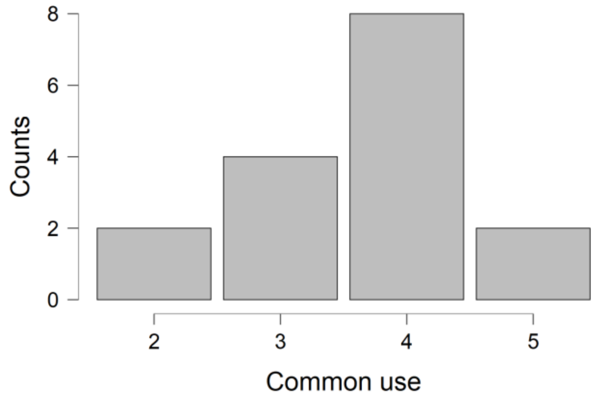

Fig. 6. Distribution of respondents' usual time representation. 1: Only clock face, 2: mostly clock face, 3: both, 4: mostly digit representation, 5: only digit representation.

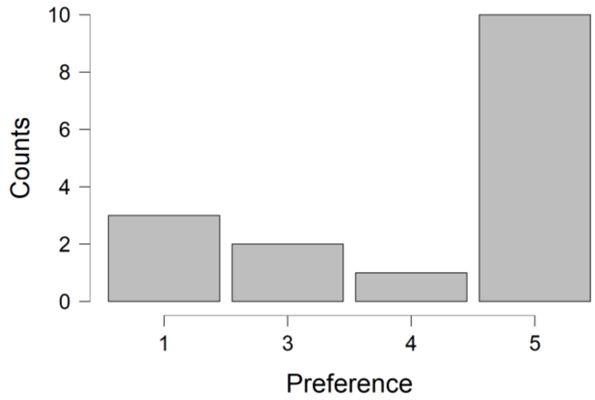

Fig. 7. Distribution of respondents' preferred time representation. 1: Only clock face, 2: mostly clock face, 3: both, 4: mostly digit representation, 5: only digit representation.

Fig. 6 shows what time representation the participants report as typically using. A majority reported mostly using digit representation. This is followed by using both, and the same number of participants reported using only digit representation and mostly clock face. None of the participants reported that they only used the clock face representation. There was no correlation between age and typical use ($r_s(16) = -.464$, $p = .070$).

Fig. 7 shows the participants preferred time representation. Clearly, a majority indicated a strong preference for digital representation, while 3 participants indicated a strong preference for clock face. None of the participants indicated a preference for clock faces. The results in Figs. 3 and 4 are quite similar, which is confirmed by a significant strong positive correlation between what time representation the participants usually use and what they prefer ($r_s(16) = 0.792$, $p < 0.001$). In other words, participants who prefer clock face will typically also use clock face and vice versa.

A significant negative strong correlation was found between time representation preference and age ($r_s(16) = -0.535$, $p = .033$).

Table 1. Clock face time tasks and associated errors (presented in chronological order).

		angle (degrees)	
time	errors	hours	minutes
10:20	5	30°	60°
07:55	4	60°	60°
04:40	3	30°	30°
10:55	3	30°	60°
01:30	1	60°	0°
07:25	1	60°	60°
02:30	0	30°	0°
05:00	0	60°	0°
06:45	0	0°	0°
08:00	0	30°	0°
11:05	0	60°	60°
12:15	0	0°	0°

There were more errors associated with the clock face (a total of 17) than the digit representation (a total of 3). We therefore analyzed the clock face errors in more detail. Table 1 shows the clock face task and the respective errors. By inspecting Table 1 it seems that the errors are higher if the clock face hands are not horizontal or vertical. The error seems especially high if the hands are at an angle of 60°. To explore this further, Table 2 was generated which lists the number of errors in relation to the angle of the hour and minute hands. According to this table most errors were associated with minute hands at a 60° angle and hour hand at a 30° angle, followed by both hands at 60° angles.

Table 2. Clock face errors according to angle of the hour- and minute hands.

	minutes		
hours	0°	30°	60°
0°			
30°		15.0%	55.0%
60°	5.0%		25.0%

Table 3. Error type.

Type of error	Percentage
closer to nearest quarter hour	45.0%
5 minutes off	15.5%
Digit reading error (misreading 15 as 16)	10.0%
after closest quarter	5.0%
Unknown	5.0%

To get insight into what may have caused these errors we tried to classify the mistake by analyzing the time set by the participant and the intended time. These results are summarized in Table 3. The errors could be classified into several distinct categories. The largest category comprising 45% of the cases involved misreading the hour hand as being closest to the nearest quarter hour, that is 3, 6, 9 or 12 hours. This was followed by misreading the minute hand by 5 minutes (15.5%) of the cases. Two of the digit task mistakes involved misreading the hour 15 as 16.

5 Discussion

The results show that the performance of the digital time representation was significantly better in terms of time to read time and errors in reading time. The time to read the time as digits was nearly one second shorter than reading the clock face (30%). The error rate with the clock face was more than 450% higher than the digit representation. In a time-critical context with no tolerance for error these differences can be what determines success from failure.

One possible explanation for this result could be that most of the participants also reported that they usually used digital time representations and preferred digital time representations. In this sense the observations could be considered biased towards the digit representation. It would have been relevant to have repeated the experiment with carefully balanced groups with the same number of participants with practices and preferences for each of the two time representations. Although relevant this scenario is not practical as we argue that the skew in preference for the digital representation is likely representative of the general population. It is thus difficult to find young participants with a preference for the clock face representation. The correlations between age and positive abilities to read clock face time further support this view. This could suggest that reading clock faces require more training and skill than digit time reading and that younger participants have been less exposed to clock faces compared to the older cohort. One may wonder if the skill to read clock faces will diminish and disappear in the decades to come in a similar manner as certain icons become less recognizable as the objects they represent become obsolete [48]? On the other hand the digit time representation did not correlate with age which indicates that the expected performance characteristics may be more robust and balanced. Another relevant observation is that those who preferred the clock face also exhibited better performance with the digital representation.

Although the use and preference patterns correlated positively, there was an interesting difference between what participants typically used and preferred. The responses to the question on what the participants typically used were centered around neutral and mostly digital, while the preferences were more extreme with most participants indicating digits, or clock face.

The observation that more errors are associated with clock hands at 60° and 30° angles is consistent with the literature which shows that assessments of angles are most accurate for 0° and 90° angles and less accurate in between [31]. The reading of the two dials requires some interpretation while digits can be read directly.

It is also interesting to observe that participants tended to round up the reading of the hour hand to the nearest quarter hour on the dial (3:00, 6:00, 9:00 and 12:00). The hour hand is shorter than the minute hand and therefore possibly harder to read. This speculation is supported by the observations which revealed a higher portion of incorrect hour interpretation compared to minute interpretations.

Our observed shorter reading times and lower error rates with digits compared to clock faces agree with the literature on clock reading among children (see for instance [10, 11]). However, the age-related preference for clock faces does not agree with Singh et al.'s study of school children's preference of time reading [12]. One key difference between the works is that children were not part of the cohort studied herein and naturally we would be able to make similar observations. Perhaps children fall in a separate category where the visual clock face is more visually interesting than the sequence of digits? Also, as noted by Boulton-Lewis et al. [11] children may not fully comprehend the meaning of time, even though they are able to read time.

5.1 Limitation

One weakness of the current experiment is the small sample size and ad-hoc cohort. The experiment was conducted during the COVID-19 pandemic and the lockdown and physical distancing complicated the recruitment of participants. There are also some errors introduced by Internet delays as it could take some time before a participant read out the time before it was recorded by the experimenters. Moreover, some participants reported a delay from when we said "go" until they could see the time task on their screen. One possible way to have reduced this problem would be to send the PowerPoint file to the participants and asked them to share the screen and control the progress, while we recorded the session. We would then have a more accurate measurement of time from the stimuli was presented to an answer was given. However, storing participants audio would mean the experiment no longer would be anonymous. The remote experiment also meant that we could not control the environment and there is a chance that some participants may have been exposed to local disturbances.

We should therefore be careful in generalizing too much from the results. However, the results give indications of challenges with the clock-face paradigm with the current technological paradigms in society that should be considered in future work.

The results indicated that the hand of the clock face angle may be related to the error rate. It is thus possible that the results are affected by the distribution of the clock face time tasks. We therefore tallied the number of clock face time tasks according to the hand angle combinations (see Table 4). The time tasks are relatively evenly distributed with approximately two tasks per configuration, but the 60°-60° task have three tasks and there are no tasks associated with full and half past tasks for 0° and 60° hour angles (for example 18:30, or 11:00). It is thus possible that this may have affected the results. Future work should carefully design time tasks that uniformly represent the clock face hand angle combinations.

Table 4. Distribution of clock face time tasks and potential bias.

	minute hand		
Hour hand	0°	30°	60°
0°	2		0
30°	2	1	2
60°	2		3

6 Conclusion

A simple experiment was conducted to assess participants ability read time represented using clock faces and digits. The results show that both the time to read the time was shorter and the associated error rate was smaller with digit time representation compared to the clock face representation. Most participants also preferred the digit representation. We also observed an effect of age as older participants were more likely to prefer the clock face, and demonstrated shorter response times and lower error rates with the clock face compared to younger participants. Despite this the response times were shorter and error rates lower with the digit representation, regardless. Implications of this work is that digit representation is preferable over clock faces especially in time-critical context with low or no tolerance for error.

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