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Original Article

Development of a Computerized Task for Measuring Time Perception

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ABSTRACT

Background: Time perception is considered as an important subject in cognitive psychology, which is essential for our understanding regarding brain mechanisms underlying human cognition and disabilities. Deficits in time perception have been found in people with both attention-deficit/hyperactivity disorder (ADHD), dyslexia, Parkinson's and Alzheimer's disease. The present study aimed at developing and evaluating the Time Perception Software with a sample including 152 Iranian students.

Methods: The computerized time perception task was designed based on time estimation, reproduction, production and time comparison method. In order to verify the reliability of the task, 30 students which were participated in the test sample repeated the test after one month. The content and construct validity were used in order to examine the validity of the task. The construct validity of the time perception task was verified by analyzing the confirmatory factor analysis using the Amos 24 software.

Results: In the modified model, the comparison factor was eliminated (CFI=0.965). The highest correlation was observed in the time estimation of 11 seconds with a correlation coefficient which was equal to 0.935 (P=0.001), while the lowest correlation coefficient was observed in the time production of 17 seconds with the correlation coefficient which was equal to 0.679 (P=0.001). The internal consistency of the task indicated that the time perception task had a near-optimal validity and its reliability was at the optimal level with the Cronbach's alpha which was equal to 0.67.

Conclusion: In order to conclude, The Time Perception Software appeared to be reliable and valid for assessing and measuring time perception in the Iranian students. This software can be used in future research investigations.

Introduction

People have individual differences regarding perception of time. Further, their ability to estimate passing of time accurately plays an important role in structuring their daily activities. When one is engaged in a desired activity, a long time seems short, whereas, when one takes on an undesired activity, the time seems to pass much slower. One does not realize the passage of time during sleep [1].

Time experience is a mental phenomenon. The passing of time can be perceived quickly or slowly depending on various situational factors, such as the richness of the experience [2-4], the presence of music [5], individual's anxiety level [6, 7], individual's level of excitement [8], and whether the individual is under the influence of psychoactive drugs [9]. Study on the psychology domain of time perception indicates variability in the perception of time in different settings. For example, the increase in environmental light, closeness to the objects [10], and activity, speed and certain emotions (i.e. anger, fear, pleasure) leads to a longer time estimation,

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whereas shame [11] results in shorter time perception. The perception of time in the form of understanding the duration, simultaneity, speed of life, and our temporary views are intertwined deeply. Grondin (2008) identified four main methods in order to measure time perception [12]. In the first method, the participant must provide a verbal estimate of the time in terms of seconds or minutes for the experimenter. The second method involves the reproduction of time, in which the experimenter presents the target time interval using continuous sound or light. Next, the participant reproduces the length of the interval. In the third method, which is called "production", the experimenter determines a target range in time units. Then, a participant produces this time interval by tapping two fingers or pressing a button at the beginning and the end of the time interval. The fourth method, which is called "comparison", is similar to the methods which are used in the traditional psychophysics. Essentially, a participant judges the relative duration of the time interval sequentially and by pressing the appropriate button declares whether the second period is shorter or longer than the first one.

The four above-mentioned methods have been used in various ways in different studies. For example, when a person is already familiar with the subject, he pays more attention to details than if the subject of attention was not known. Cognitive psychologists differentiate between two paradigms. In the first paradigm, which is called prospective timing, subjects are made aware of the time-related experiment prior to performing the assignment. On the other hand, in the second paradigm, which is called retrospective timing subjects receive no knowledge regarding the assignment [13-15]. Researches indicates that in prospective timing, time estimation by the subject is longer than the actual time, encouraging researchers to use natural situations, and not laboratory conditions, in order to perceive time [16]. Therefore, it is necessary to consider this in developing the laboratory tools.

Among many reasons for developing different time perception methods, are problems which are associated with the participants' motivation in using counting techniques [17] offered three solutions in order to resolve this problem. Asking the participant not to use any counting methods is considered as the first solution. The second solution is concerned with the articulatory suppression, i.e. the participant is asked to sing during the test. Finally, the third solution involves using interference task variables in the test. According to the results of the study which was conducted by [17], since each of these solutions has advantages and disadvantages, giving no counting instructions to the participant is considered as the easiest and most efficient method.

Despite a large number of studies on time perception, there are still some important questions that have remained unanswered. Most of the findings from time perception models confirm the existence of underlying cognitive processes in time perception. Study on patients with Parkinson's disease showed a disturbance in time estimation and time reproduction [18]. For estimating time and its usage in regulating motor response in order to reproduce the time, it is necessary to maintain a series of information in short-term memory and active memory, which is not possible due to damage of prefrontal cortex in these patients. On the other hand, it has been shown that active memory is defective in children with attention deficit and hyperactivity disorder. Deficits have been found in temporal reproduction and production estimations in hyperactive children [19], male delinquents [20], impulsive boys, and impulsive adults [21]. Also, many studies revealed a defect in correct perception of time in dyslexic individuals [22].

In these studies, researcher-made tasks were used in order to measure time perception. In these tasks, different tools were implemented such as turning an actuator on and off such as lamp, the reciprocation of colored circles [23], generating sound by knocking on the table (1), estimating time after playing a computer game [24] or showing images on the computer screen [25]. In order to simulate the natural environment in the laboratory, creating software that can measure time perception accurately and can account for all the existing limitations, can contribute to the researches in this field. Computerized psychological testing systems have the potential in terms of being practical and cost-effective [26, 27]. The present study aimed at constructing and evaluating the Time Perception Software.

Methods

The research method was descriptive and it was based on instrumentation studies. In order to conduct the study, 152 students were selected. The statistical population of this research includes all students studying in Shahid Beheshti University. In this research, convenience sampling method was used. Due to the long duration of the test, students were asked to participate voluntarily in the study and they have received educational scores as a gesture of our gratitude. Students who were reluctant to participate in the test received scores for other activities. Qualification criteria for participating in the test included being familiar with computers, not having movement problems, and not having severe vision problems. If the rules of the test were not observed entirely by the test takers, the test was considered as incomplete. Students were asked to sign a consent form which was developed for the study. The students were aged between 18 and 32 years old (M=20.59, SD=2.885). Students were participated in tests in a quiet room at the Center of Social Psychology, Shahid Beheshti University. Each test lasted twenty minutes. In order to test the reliability of the research task, 30 participants were re-tested one month later. The computer version of the task was made by MATLAB software and the data were analyzed using SPSS AMOS 24.

Instruments of the Study

Designing Time Perception Task

The computerized time perception task was designed based on four methods which were stated in the literature

[12]. In order to evaluate these methods, some related studies were used [12, 28-34]. The computer test was designed in MATLAB software for Persian speakers. MATLAB is a programming platform which uses a matrix-based language which is known as MATLAB language. MATLAB is a great tool for computer programming and data analysis. It allows creating large and complex programs that implements specific algorithms. The software can be converted into other languages easily. In addition, the test was designed in such a way that responses and deviations from real-time were stored in Excel. The designed test allowed the researchers to implement each of the four main stages in method separately.

Procedure

First, test participants were instructed regarding the use of the computer, including pressing the Enter and Space buttons, and how to work with the software. The participants were asked to refrain from using any counting techniques such as knocking, fingers, or counting seconds [35].

The specifications for the hardware and the software are outlined in Table 1.

Table 1: The specifications of the hardware and the software

Processor	**Intel Core i5-4300U CPU @ 1.90 GHz 2.50 GHz**
Random-access memory	4 GB
System type	64-bit Operating System
Windows edition	Windows 10 Pro
Matrix Laboratory	MATLAB R2015a

Implementing the Method

The time perception task was designed and implemented in four steps accordingly:

Time Estimation Test

The participant was unaware of the relationship between the test and time perception, and attention has been paid to retrospective timing. A blue screen was displayed on the computer monitor for 11 seconds, and the participant was asked how long it takes that this screen is appeared in seconds. The next steps were in the form of prospective timing, which were presented to the participant in intervals of 11, 17 and 25 seconds. The interval of 11 seconds was included no interruption while the other two intervals were conducted with interruption. When interruption was required, the screen was divided into nine equal rectangles, which were selected randomly. The selected rectangle would be darker than the background for a random amount of time and the participant was asked to press the Enter button after observing the fifth rectangle. This was done to ensure that a rectangle was not selected twice in succession, and that the random time selection was a quarter of the total time for that stage of the experiment for displaying the first four rectangles.

Time Reproduction Test

This part of the test included three steps. The Time reproduction method was described for the participant in the software. The participants could produce time by holding the Space key. However, it should be noted that the interruption was appeared as turquoise- colored rectangles on the screen during the time production and the participant should write the number of interruptions. The random time was considered in 3-second intervals for displaying rectangles. We were confident that no rectangles were selected for a second consecutive time since the computer compares the number of rectangles which were displayed with what the participant enters at the end. The participant proceeded to the next step not receiving any computer-generated messages if counting was performed correctly. However, if the participant counted the number of rectangles incorrectly, the participant received a computer-generated message indicating the number of rectangles has not been entered correctly although the error was within an acceptable range. On the other hand, if the error exceeded one, the participant could not enter the next stage and was asked to repeat this part of the test. If the participant failed to write the number of rectangles, he could not enter the next stage of the test. In third step, similar to the time estimation test, three intervals of 11, 17, and 25 seconds were presented as a blue screen, which the participant should produce through interruption.

Time Production Test

This part of the test was included three parts. The participants were asked to produce the requested time by holding the Space key in each step, against the interruption.

Comparison Test

This section also was included three parts. The screen was divided into two equal parts vertically. In each part, a turquoise-colored circle was appeared on both sides of the blue screen. At the end of each step, the participant was asked to compare which of the circles had a longer presence on the screen.

Results

The validity of the task was investigated using two methods.

Content Validity

The formal validity of the developed software was reviewed and was approved by the supervisory professors (3 experimental psychologists with PhD degree).

Construct Validity

This validity represents to what extent the results which were obtained from using a measuring instrument are congruent with the theory upon which the test is based. Table 2 presents the mean and the standard deviation of three steps of the time perception task: Estimation, reproduction and production.

The results which are related to the percentage of error in time perception were analyzed in 11 stages of the

Table 2: The mean and standard deviation in three steps of estimation, reproduction, and production

Variable	Mean	Standard deviation
11-second estimation without awareness	-1.125	7.368
11-second estimation with awareness	1.361	6.898
11-second estimation with interruption	1.51	9.92
17-second estimation with interruption	-0.93	10.25
25-second estimation with interruption	-3.951	13.171
11-second reproduction	3.407	7.23
17-second reproduction	-1.096	4.97
25-second reproduction	-4.186	7.258
11-second production	1.843	4.865
17-second production	3.072	8.004
25-second production	4.355	11.353

test by repeated measures (within the subjects) and the assumed Sphericity is presented in the Table 3.

The results showed that there was a significant difference when the level of significance was less than 0.001 in time perception in the 11 stages of the test.

The results indicated that the participant estimation was less than the real value when the participant was unaware of the relationship between the test and the concept of time. Whereas, the estimation was greater than the real value when the participant was informed of the objective of the study, the estimation of time. In the next step, the interruption will make the estimation less than the real value, which will increase as time elapses.

In the reproduction test, the reproduction time is considerably less than the real value when the participant is unaware of the relevance of the test with the concept of time. However, when the participant is aware of the type of test, reproduction is greater than the real value although an increase in the time and the presence of interruption make the participant underestimate the time.

In the time production test, the participant overestimated the time in all three steps, and this increase is observed in the production by increasing the time difference. In all three steps, an increase in time leads to the increase in the standard deviation, indicating the greater dispersion of respondents. The construct validity of the time perception task was verified through analyzing the factor analysis using the Amos24 software by comparing the hypothesized model with the null model.

The results are presented in Figure 1 and Table 4.

As it is illustrated in Figure 1, time estimation and time reproduction have a reverse and significant relationship while production and reproduction have a positive and significant relationship and the factor of time comparison is an independent factor.

Based on Table 4, the fitness indicators present a suitable fitness from the experimental data.

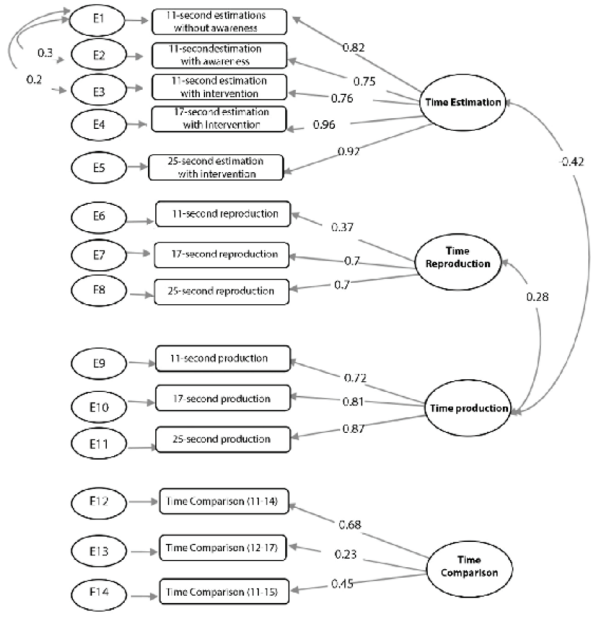

Figure 1: A structural factor model of the time perception task

As the factor loading of the time comparison indices [17–12] and [11–15] are not significant in the time comparison factor, the modified factor model and the model fitness indicators are shown in Figure 2 and Table 5.

Cronbach's alpha and test-retest methods were used in order to evaluate the reliability of the test. Thus, the test was performed on 30 participants one month later, and the Pearson correlation test was used in order to evaluate the results (Table 6).

The correlation which was obtained in the pre- and post-test conditions is significant at different stages of time perception task. The highest correlation coefficient of 0.953 was observed in the time estimation of 11

Table 3: Repeated measures of 11 stages in Time Perception Test

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Sphericity Assumed	488358.449	10	44396.2	16.4	<0.001
Error(factor1) Sphericity Assumed	4378804.145	1617	2707.980		

Table 4: Fitness indicators of the model which are observed with the zero model

RMSER	CIMIN/DF	PCFI	CFI
0.080	0.95	0.745	0.929

Table 5: Fitness indicators for the model which is modified with the zero models

RMSER	CIMIN/DF	PCFI	CFI
0.075	1.834	0.684	0.965

Table 6: Test-retest correlation coefficient of time perception task with a 30-day interval

Time estimation		Time reproduction		Time production	
Stage	**Correlation coefficient**	**Stage**	**Correlation coefficient**	**Stage**	**Correlation coefficient**
Time estimation without awareness	0.827**	Time reproduction (11 s)	0.853**	Time production (11 s)	0.704**
Time estimation with awareness	0.941*	Time reproduction (17 s)	0.919**	Time production (17 s)	0.679**
Time estimation (11 s) with interruption	0.953**	Time reproduction (25 s)	0.833**	Time production (25 s)	0.850*
Time estimation (17 s) with interruption	0.940**	-	-	-	-
Time estimation (25 s) with interruption	0.944**	-	-	-	-

*P<0.05, **P<0.01

seconds (P=0.001), while the lowest correlation coefficient (0.679) was observed in the time production of 17 seconds (P=0.001).

Further, the reliability of the task was evaluated through Cronbach's alpha and the average factor loads are presented in Table 7.

As seen in Table 7, the internal consistency and average factor load are suitable since the reliability criteria for time estimation and time production factors are met, whereas the reproduction process does not have the suitable reliability. The total inner consistency of the task is close to optimal point although, its reliability is optimal.

Discussion

The software which was used in this investigation had the following general capabilities: In order to minimize human error, all calculations were done using the software. In order to prevent undesired execution of the program, the user must be verified before starting each section of test. The program was written in such a way that that it cannot enter the next step until the user gives a correct input in response to the software. If the test is stopped before completion, it is possible not only to retrieve the data which was entered, but also to resume the test without needing to start from beginning. Finally, all random events are in a controlled format, which is the main reason regarding why they are listed in the SECTION part of the run method.

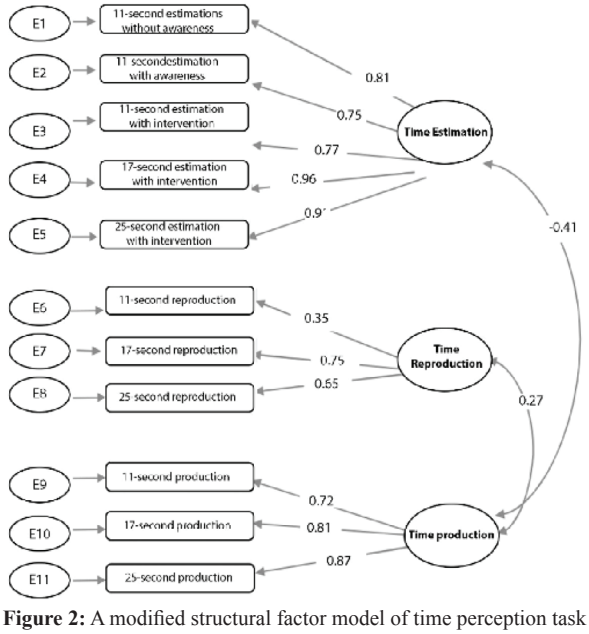

Figure 2: A modified structural factor model of time perception task

The content validity of the time perception task was confirmed by experts in the field of experimental psychology and the findings were consistent with theoretical foundations. The results at the stage of the time estimation confirmed the findings about the attention models in literature. The results of our investigation indicated that the time was estimated less than the real value with an increase in the number of interruptions and the sources of attention. Further, as long as the participant is unaware of the subject of the test, he underestimates the time. Furthermore, the participants underestimate the time as the provided time interval increases. These findings are consistent with theoretical foundations [29]. The results indicated that in the time reproduction of 17 and 25 seconds, in which the interruption was present, the produced time was less than the real value, which is against the stage of the time production, in which the time was greater than the real value which was produced by the participants. This process can be explained by the Attention Gateway model. Based on this model, time perception is related to attention processes in short-term and long-term memory. In the process of time production, less attention is devoted to the passage of time and the goal achievement, since the required time,

Table 7: The reliability indicators of the time perception task

Factors/indicator	Estimation	Reproduction	Production	Total
Item No.	5	3	3	11
Cronbach's alpha	0.917	0.576	0.791	0.67
Factor loading mean	0.85	0.59	0.80	0.74

is prioritized. Thus, the time estimation is more than the real value. However, attention is devoted to the passage of the time in the reproduction stage. Since the working memory is active in this section and the small time pulses are allocated to the target. Thus, it is expected that what is produced in the memory over the time and accordingly the reproduction time to be less than the real value.

In the time production test, the participants overestimated the time in all three stages and this increase was observed in production by increasing intervals. Although, the increase in time is not significant in the second stage, where the production is equal to 17 seconds and the difference is small compared to the previous and next stages, the observed increase in the production is also significant (MD=2.51, P=0.003) as time interval increases. Therefore, in the first three stages, "estimation, reproduction, and production of time", the results are in line with previous findings [36-38], indicating the validity of the test. The time comparison factor was identified as an independent factor in the first model and was eliminated in the modified model. At this stage, the interruption was not used and instructions were only given for counting according to recommendations which were presented by [17]. However, it seems that the instructions do not suffice. Despite the participants' acquaintance with the previous stages and the lack of importance regarding correct or false responses to the test, they disengaged themselves due to the lack of interruption and they preferred to use methods such as counting time in order to get their correct mental response. According to [39], although the correct response rate which is more than 50% indicates that the participants are involved in the task actively and the results are not accidental, this issue reduced the correlation of this factor with other factors and was eliminated in the modified model accordingly.

A high correlation was obtained in investigating the reliability of the test by using the re-test method. The highest correlation was found in the time estimation of 11 seconds (correlation coefficient was equal to 0.935, P=0.001) and the lowest correlation coefficient was obtained in the production time of 17 seconds (correlation coefficient was equal to 0.679, P=0.001, indicating that the reliability of the test is acceptable. The internal consistency of the task indicates that the time perception tasks have a good reliability with the Cronbach's alpha which is equal to .67.

The software is convertible into other languages easily. Considering the limitations, it also helps to simulate the real environment in a laboratory environment. Since the use of this tool is very simple, it is possible to use it in groups with different physical and psychological conditions. The research applicability of this tool is possible for various clinical problems in different age groups like people with attention-deficit/hyperactivity disorder (ADHD), dyslexia, Parkinson's and Alzheimer's disease.

Conclusion

The research applicability of this task is considered in psychological time. Time perception has attracted a lot of attention as a topic for research. Conducting such studies in clinical and educational matters like studies in ADHD, in Alzheimer and other disabilities requires using valid and reliable tools. Furthermore, it is suggested that the interruption should be used during the time comparison period as in the previous steps in order to design future versions in future studies. The research had some limitations, including the sampling method which was done through non-random selection of the subjects. It is suggested to conduct this research in other populations in order to modify the methodological limitations. In addition, the effect of lack of memory and learning cannot be guaranteed and isolated, thus for achieving greater certainty, the validity was also calculated using the internal consistency method. It is also suggested to compare the present task in different groups with different psycho-physical conditions.

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