Tabled-based neuropsychological assessment. A promising study on a Neuropsychological Screener.

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NOTE: this study is performed by students of the Vrije Universiteit Amsterdam. Guided by Dr. J.B. Deijen, from the department of clinical neuropsychology and Drs. L. de Vroege, at that time working as a neuropsychologist for Metrisquare GmbH. See acknowledgments for further disclosure of interest.

In the last couple of decades a lot of research on cognitive abilities has been executed in the clinical neuropsychology. Examples of such cognitive abilities among many others are memory, planning, attention and mathematics. These abilities are usually tested with the so-called “paper and pencil-tests”. The disadvantages of paper and pencil-tests are numerous. For instance they acquire great use of paper, which go hand in hand with a lot of money. Besides the costs, the use of these kinds of tests is also bad for the environment. A solution to overcome this problem could be using tablet technology in the diagnostic process. Due to the technology nowadays people work on a computer for a lot of purposes. In western countries almost every household owns at least one computer. A study of the Central Bureau of Statistics (CBS) shows that 94% of all households in the Netherlands owned a computer in 2012 (Centraal Bureau voor de Statistiek, 2013). Few studies have examined the advantages of using a tablet for cognitive testing in neuropsychology. There are only a number of studies known to the authors that examined tablet-technology in cognitive testing. Results of these studies remain equivocal (Bauer et al. 2012). The current study was performed to investigate whether or not the paper and pencil-tests could be replaced by a tablet-based version.

Bauer et.al. (2012) expect that the use of computers or tablets for neuropsychological tests will increase over the years. A computerized test should meet a couple of requirements, such as test reliability and validity, certain technical specifications, methods for the privacy of the client and so on. According to Bauer et.al. (2012) computerized tests have a lot of advantages over paper and pencil-tests. For example, a shorter assessment time, lower costs of test administration, test scoring, and a more accurate measure of reaction time. With all taken together, computerized tests seem to have more advantages than paper and pencil-tests.

Fazeli et.al. (2012) have examined the differences in cognitive performance between older computer users and none-users. They also studied the influence of previous computer experience on the performance on computerized cognitive tests. The expectation was that individuals who frequently use computers perform better on cognitive tests, on computerized tests as well as on paper and pencil-tests. Furthermore, they expected a positive relationship between computer experience and performance on computerized cognitive tests. The study of Fazeli et.al. (2012) showed that computer users were younger, Caucasian, were higher educated and had better cognitive performance. None users had poorer performance. It also showed that computer experience had a positive relationship with the performance on cognitive tests on the computerized and paper and pencil-tests. This means that the performance on computerized tests is not influenced by whether or not the participant has computer experience.

The cognitive functions measured in the current study were spatial ability, the ability to plan and working memory. These functions were tested with paper and pencil-tests and on a tablet and the results are used as normative data. There is an important difference between computerized tests on a desktop or laptop versus a test on a tablet. The tablet used was developed to give the client the idea and feeling that one is just writing on a surface, just like with paper and pencil-tests. The tablet is flat, and the client should write and draw on it with a certain pen. In this way, assessment of the digital tabled-based test nearly reaches paper and pencil-testing but with the advantages of tabled-testing.

A possible problem with test assessment on a tablet could be computer anxiety (Chua, Chen, & Wong, (1999). A meta-analysis, conducted amongst university undergraduates, showed the relationship between computer anxiety and gender, age and amount of computer experience. According to this meta-analysis female participants had slightly more computer anxiety than male undergraduates, but due to several other conclusions, this relation is inconclusive (see Chua, Cehn & Young, 1999 for a description). Moreover, they found that older people experienced more computer anxiety than younger people, but this was only proven in studies with a wide age range. Furthermore, computer anxiety is inversely related to the amount of experience one had with computers (eg. when computers were frequently more used during life span, computer anxiety decreased). Brosnan (1998) examined the effect of computer anxiety on performances on computerized tests. The outcome showed that computer anxiety is directly related to the performance on tests. But Brosnan (1998) measured another variable: self-efficacy, which was related to how the participant achieved the outcomes on tests. The general outcome suggested that individuals with high computer anxiety achieved less correct answers and a slower completion time, but the reaction time was influenced by a third variable, namely low self-efficacy.

The goal of the current study was to investigate whether the paper and pencil-tests could be replaced by tests on a tablet by means of a normative study. It was hypothesized that measurements by paper and pencil corresponded with those gathered by tablet. In addition, the effects of computer anxiety on the performances were investigated. It was expected that participants with higher anxiety for computers would perform worse on tablet than on the paper and pencil-tests than participants with low or no computer anxiety.

Method

Participants

Sixty healthy people were participating in the current study. These participants are between 19 and 88 years old (M = 34.14, SD = 18.92). The group of participants contains 32 females and 28 males. Within these participants 16.7% has had a low education, 63.3% a middle education and 20.0% has had a university education. Years of education ran from 6 to 23 years (M= 16.93, SD = 3.21). The participants did not have severe mental or physical disorders. Participants were recruited in various places in The Netherlands and asked to voluntarily do the cognitive tests. The participants did not receive a reward for volunteering. They received information about the study and signed informed consent.

In/exclusion criteria

Participants had to be at least 18 years old and in healthy condition. If participants were unable to read accurately, had any form of mental disorder (this is controlled for during a short diagnostic interview beforehand) or did not want to participate (at anytime during the test), they were excluded from this study.

Measures

This study had several kinds of measures. The measures were a tablet and paper and pencil version of a cognitive test battery, a short anamnesis, and the Beckers and Schmidt Computer Anxiety Scale (BSCAS) (Beckers et al. (2007). The selection of cognitive tests of the NPS testbattery existed of three tests, namely the Blockreasoning Test, Streetmap, and the Trailmaking Test (TMT). The selection of three tests which are used in this particular study, are part of a neuropsychological screener developed by Metrisquare-Europe GmbH. At the start of this project the automatic analyses module for the screener as whole was partly finished. Therefore, three tests were selected in order to obtain normative data for the specific screener.

The Blockreasoning Test measures spatial ability. In this test the participant is asked torecognize a block pattern from several views. The test exists of ten block patterns which are divided in two categories. The first seven tasks show a block pattern with an arrow in a certain direction, with underneath three views. The participant should choose the view which coincides with the example that is given (the pattern that shows the arrow). In the second part of the test, a pattern is displayed and the participant is asked to select a block pattern with arrow, out of three possible options.

The ability to plan was measured by using the Streetmap test. This test consists of a map, with a description underneath of the route to follow. On the map there are several things to see, for instance buildings, roads, bus stops, a park, and a forest. The participant gets the instruction to accurately read the description beforehand, and when one is ready he/she should draw the correct route. When the participant doesn't read the description accurately, he/she could be fooled by two pitfalls.

Working memory is measured by using the Trailmaking Test (TMT). This test exists of five components. In the first part of the test a black circle was shown with surrounding circles with numbers in it. The participant was asked to draw lines with the pen, beginning at the black circle and draw to number 1. After that the participant has to draw a line back to the black circle and go on to number 2, and so on until reaching the number 9. The participant has to repeat that until he/she has had all the numbers ending with the black circle. As soon as the participant began drawing, the pen should not leave the paper anymore (the latter counts for every component of the test). In the second part of the test characters were presented in the circles instead of numbers. The instruction of this task was still the same as the first, both tests measure processing speed. In the third component of the TMT there were numbers and letters in the circles. The participant should start with the black circle and draw to number 1, then to the black circle, and then to the letter A, and so on. This part of the test measures sustained attention. During the fourth part of the test the participant sees numbers again. However, during this subtest the numbers were shown for a short period of time. The participant should remember the location of the numbers, and draw the lines in the right sequence when the black circle was visible. In the last component of the TMT the numbers were again shown for a short time, but this time the participant should draw the line to a number immediately after the number was shown.

There were two parallel versions of the whole test battery, version A and version B, on tablet as well as on paper.

The anamnesis exists of questions about age, gender, education, hand preference, and also about the use of alcohol, drugs and medicine. The BSCAS measures the amount of computer anxiety (Beckers et al. (2007). It measures six factors: 1) computer literacy (skills), 2) self-efficacy (the confidence of one selves to learn how to use computers), 3) physical arousal in the presence of computers, 4) affective feelings towards computers, 5) positive beliefs about the benefits for society of using computers, and 6) negative beliefs about the dehumanizing impact of computers. It contains 32 questions, with responses on a 1 to 5 likert scale.

Procedure

The current study is executed to investigate whether paper and pencil versions of neuropsychology tests could be replaced by a tablet version. In addition, computer anxiety was taken into account, because it could possibly influence the performance of participants on the tablet tests.

The participants took the test twice, namely once on the tablet and once the paper and pencil-test. Half the participants first took the tablet test with version B and after that the paper and pencil version A, while the other half of the participants took the paper and pencil version A first and then version B at the tablet. This kind of counterbalancing is necessary to prevent possible learning effects. After a participant took the test on the tablet, he/she had to fill in the CARS, the computer anxiety rating scale. The test on the tablet started with a short anamnesis and a few questions about sight, alcohol and drug use, hours of sleep and caffeine use. After that the House Tree Person test was taken, in which the participant has to draw a house, tree and a person. This test was to let the participants get used to the tablet. After that the test battery was taken. The paper and pencil-test also began with a short anamnesis, after which the test battery directly followed. The time between the first and the second test was at least one day. This short intermission was possible because of the counterbalancing. The duration of the test ranged from 30 minutes to 1 hour, dependant of the participant. Finally, the tests were taken at several places in the Netherlands, most of them near Amsterdam and Utrecht. Further, the tests were taken at several moments of the day and by a total of six test leaders.

Results

The purpose of the current study was to examine the possible differences between the performance on neuropsychological tests on tablet versus paper and pencil-tests. This study also examined the influence of computer anxiety on the performance on a neuropsychological test versus tablet.

Data

Some data adjustments had to be done prior to conducting the analyses. The items of the Trailmaking Test were divided in 3 parts. Since items 1 till 3 measured processing speed they had to be combined. Items 5 till 9 had to be combined as will since those measured working memory. Outliers were excluded from analysis when more than 2 standard deviations of the mean were reached. One participant met this criteria for all subtests since he/she finished the test battery in such a long time that the results were labelled as unreliable. Furthermore, a couple of participants were excluded from analysis for some subtests since they reached a deviation of more than 2 standard deviations of the mean. During analysis a significance level of $p < .05$ was used.

Computer anxiety

Computer anxiety was divided into three categories, namely low computer anxiety, medium computer anxiety, and high computer anxiety. This was based on the 33.33rd and 66.66st percentiles that cut the scores in three groups.

Statistical analysis

The current study has examined the differences between the performance on neuropsychological tests on tablet and on paper and pencil-tests. To examine the differences in performance on the Block Reasoning Test between tablet and paper and pencil, a repeated measures analysis of variance was conducted. It appeared that the number of correct responses were higher on paper and pencil (M = 9.25, SD = 1.25) than on tablet (M = 8.61, SD = 2.27), which is a significant difference, with small effect (F (1, 50) = 4.77, p = .034, η^2 = .087). Repeated measures analysis of variance also shows that participants' reaction times were lower on paper and pencil than on tablet; on half of the items of the Block Reasoning Test. Meaning responses were faster at paper and pencil than on tablet on these items. There were no significant differences on the other items. The effects, means

Table 1. Differences in reaction time on Block Reasoning Test between tablet and paper-and-pencil test.

		F	p	Partial η^2
Item	1	0.99	.332	.050
	2	5.72	.027	.231
	3	1.66	.213	.080
	4	7.41	.014	.281
	5	1.33	.264	.065
	6	0.27	.608	.014
	7	2.17	.157	.103
	8	6.07	.023	.242
	9	12.11	.003	.389
	10	10.01	.005	.345

and standard deviations of the differences in reaction time on the Block Reasoning Test are listed in Table 1 and Table 2.

Table 2. Mean reaction times on Block Reasoning Test on tablet and paper-and-pencil test.

		Measurements	*M*	*SD*	*N*
Item	1	Tablet	4.04	2.26	20
		Paper-and-pencil	3.47	1.30	20
	2	Tablet	3.70	1.61	20
		Paper-and-pencil	2.97	1.00	20
	3	Tablet	4.16	2.13	20
		Paper-and-pencil	3.49	1.21	20
	4	Tablet	6.01	2.72	20
		Paper-and-pencil	4.18	1.28	20
	5	Tablet	4.68	3.30	20
		Paper-and-pencil	3.82	1.57	20
	6	Tablet	3.69	2.81	20
		Paper-and-pencil	3.34	1.16	20
	7	Tablet	4.19	2.46	20
		Paper-and-pencil	3.40	1.37	20
	8	Tablet	8.36	7.37	20
		Paper-and-pencil	4.20	1.31	20
	9	Tablet	8.38	4.51	20
		Paper-and-pencil	5.26	1.92	20
	10	Tablet	7.48	3.15	20
		Paper-and-pencil	4.82	2.39	20

A non-parametric related samples McNemar test was conducted to examine the differences in performance on the Streetmap between tablet versus paper and pencil. This analysis shows that the distributions of the values of the number of corrected responses on the Streetmap were equally distributed ($p = .108$).Meaning, no differences in performance were observed on the Streetmap between tablet versus paper and pencil. A repeated measures analysis of variance showed that there was a difference in solving time between tablet versus paper and pencil, with large effect (F (1, 53) = 58.83, $p < .001$, $\eta^2 = .526$). Participants completed the test faster on paper and pencil (*M* = 123.70, *SD* = 50.12) than on tablet (*M* = 396.30, *SD* = 257.55).

A repeated measures analysis of variance on the TMT showed a significant difference in reaction time on the items 1 to 3 of the TMT between tablet versus paper and pencil, with large effect (F (1, 48) = 28.33, $p < .001$, $\eta^2 = .371$). The participants were on average faster on paper and pencil (*M* = 38.92, *SD* = 14.97) than on tablet (*M* = 48.01, *SD* = 22.14). There was also a significant difference in the reaction time on item 4 between tablet and paper and pencil, also large effect (F (1, 48) = 12.45, $p = .001$, $\eta^2 = .206$). Participants were faster using paper and pencil (*M* = 15.07, *SD* = 4.50) versus tablet (*M* = 17.48, *SD* = 6.57). There was no significant difference in reaction time between tablet versus paper and pencil on the items 5 to 9 (F (1, 48) = 3.01, $p = .089$). A number of repeated measurements analysis of variance were conducted to examine the differences between number of correct responses on the TMT between tablet and paper and pencil. The effects are presented in Table 3. Three items of the TMT there differed with regards to corrected responses between tablet versus paper and pencil.

Table 3. Differences in corrected responses between tablet and paper-and-pencil on the items of the TMT.

		F	*p*	Partial η^2
Item	1	2.04	.159	.034
	2	0.00	1.000	.000
	3	4.79	.033	.076
	4	0.09	.766	.002
	5	9.54	.003	.141
	6	6.01	.017	.094
	7	0.00	1.000	.000
	8	1.34	.252	.023
	9	0.18	.674	.003

Discussion

The main goal of the current study was to investigate whether or not ‘paper and pencil-tests’ could be replaced by tablets for neuropsychological tests. Meaning, the performances on both measure-instruments should be approximately the same. Furthermore, the effect of computer anxiety on the performance on the tablet was examined. It was hypothesized that the performances on paper and pencil-tests were about equal to the performances on tablets. It was also expected that participants with higher computer anxiety would perform worse on a tablet than on paper and pencil-tests, compared with participants with low or no computer anxiety.

Current study shows that there were a few differences in performance on neuropsychological tests distributed by paper and pencil versus tablet. On the Block Reasoning Test and Streetmap, participants perform slightly better on paper and pencil. However, differences were small and fewer participants were included for the analysis. Moreover, the fact that people are not yet used to work on a tablet in this setting can count for these differences. The performances on the Trail Making Test were equal between paper and pencil and tablet. All in all, there are some minor differences between performances on tablet and paper and pencil. However, these differences were small or only accounted for a few items per test. These differences mainly arose when looking at the time in which the participants solved the test. Whether or not participants succeeded in the test did not differ that much between tablet versus paper and pencil.

This study shows that computer anxiety does not interfere with the performances on neuropsychological tests assessed on a tablet. This means that, as opposed to the outcomes of Brosnan (1998), participants with high computer anxiety did not perform worse on the neuropsychological tests on tablet than participants with low or no computer anxiety. This finding means that individuals with or without computer anxiety can accomplish tests on tablets, without influencing their performance badly.

According to Bauer et al. (2012) computerized tests have more benefits than paper and pencil- tests, because it can accurately measure reaction time, it can process the results easily and fast and it is useful for the test administrator. This study confirms these benefits of a tablet since measurements reaction times and percentage correct/incorrect answer can be analysed without any effort. Also, tablet technology allows the practitioner to harvest more data from the same tests. This leads to one of the limitations of our study since some data was difficult to compare between paper and pencil versus tablet since some measurements were not able to measure by hand by the test administrator (eg. inter-item reaction time. For instance, for the results of the reaction times of the Block Reasoning Test we could only include 20 participants since data collection from the other participants failed. Because of these limitations, the results on this specific item have to be interpreted carefully. All in all, the automatic data collection of the tablet has proven to be a solid strong argument in favour of using tablet technology in neuropsychological practice.

Another shortcoming of the current study is the fact that six different people collected data. This could have led to differences in the way the tests were administered. However, the study sample has proven to be a good representation of the population. Moreover, counterbalancing was used to rule out ranking effects.

In sum, the current study shows that there are a couple of minor differences in performance on neuropsychological tests between tablet versus paper and pencil. However, these differences could be explained by the fact that people are more used to working with paper and pencil. Besides, collecting norm data for this specific tablet test can abolish these differences. However, future research is necessary to investigate whether tablet technology could replace paper and pencil-tests. These studies should gather data from a larger population and collect them by a single (or at least less possible) test administrator.

All in all, a promising finding of this study states that neuropsychological testing on a tablet is beneficial for practitioners and looks more than promising. Furthermore, computer anxiety showed no negative interaction with performance on a tablet, so individuals with high computer anxiety could just perform tests on a tablet as well as individuals with low or no computer anxiety. Future research is recommended in order to provide more and solid norm scores for tabled-based neuropsychological tests.

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