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Advancements in Dexterity Measurements: the digital Nine Hole Peg Test

Validation results of a digital innovation in dexterity assessment

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Abstract: Digitalization in the healthcare sector is progressing rapidly. In the field of measuring instruments for manual dexterity, digitization has resulted in major limitations in terms of ease of use and usability. This study describes the development of a digital nine-hole peg test (dNHPT) for assessing hand dexterity that can be used just as easily and quickly as the original nine-hole peg test. The extensive validation of the dNHPT includes the investigation of validity, reliability, clinical utility and user-friendliness

This paper presents the validation of clinical utility and usability of the dNHPT. The comparison of the original nine-hole peg test (NHPT) und the dNHPT show similar clinical utility of the dNHPT and the NHPT (74% of all ratings of dNHPT are equal to or better than the NHPT) and good to excellent System Usability Scale Scores of 78 (CI95: 75;81) and 85 (CI95: 80;89). Several recommendations for further development of the dNHPT were identified.

The newly developed dNHPT presented here supports the quality of data collection through automated time measurement and result presentation and shows good usability and clinical utility ratings.

Keywords: Clinical utility, digital Nine Hole Peg Test, development, measurement instrument, validation

1 Introduction

Clinical measurement procedures are an essential part of modern healthcare. They are used to assess the current condition of a patient, the progress of a disease or the effect of a treatment [1]. In neurological disorders, the Nine Hole Peg Test is the gold standard [2] to assess hand dexterity [3]. The task for the person being tested is to place nine pegs one by one in holes on the test board and afterwards remove them one by one. The task is guided by a therapist who also records the time with an additional stopwatch. The time required for the task is the result of the NHPT [4]. The NHPT is widely used due to its simplicity and rapid measurement [5].

The implementation of the standardized measurement procedure [4] requires the therapist to monitor the control for error-free execution and to measure the time at the same time. The use of a stopwatch is not very common today, which can affect the reproducibility of collected data. Some research has focused on digitizing the measurement with the NHPT [6–10] in order to improve quality and reliability of the data collected. Additional equipment required for these digitized variants of the NHPT, such as cameras, sensors and software, lead to significant changes in user requirements [11].

Our new approach focuses on the digitization of the NHPT without losing the simplicity and speed of measurement. We have developed a digital Nine Hole Peg Test (dNHPT) that supports the measurement of hand dexterity with automatic time measurement, result presentation and error control, which should be as simple and quickly be used as the original NHPT. The prototype developed has undergone extensive validation, the results are now presented here.

2 Methods

The dNHPT was designed according to the dimensions of the original NHPT [4] using CAD and 3D printing and equipped with digital electronics (see Figure 1, right). Hall sensors in the test board detect the insertion and removal of the pegs. The additional control box contains the microcontroller to control the system and the input and output elements.

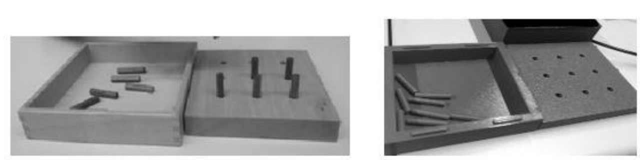

Figure 1: Original NHPT (left) and digital Nine Hole Peg Test.

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The system provides automatic time recording (by pressing a button at the start and end) and the output of the result (seconds required for the task). The state of the art of product development [12–14] was used for development and verification. More detailed data on the development can be found in an earlier publication [15].

The study design for validation of the dNHPT was developed, planned and implemented in accordance with the COSMIN (Consensus-based Standards for the selection of health Measurement Instruments) guideline [16]. For examination validity, reliability and agreement, the dNHPT was compared with the NHPT in laboratory studies. The study design corresponded to a repeated measurement with crossover design and two raters. The concurrent validity, agreement with the NHPT, test-retest reliability and interrater reliability were determined [15]. The fact that a test is valid and reliable does not mean that it is also clinically useful. Therefore, clinical utility was evaluated in the validation process. The dimensions of clinical utility defined by Fawcett [17] were used for this purpose (see Table 1).

Table 1: Dimensions and subcategories of clinical utility [18]

Acceptance	**Description / guiding questions**
Stakeholders	Is the test accepted by clinic management, lay observers or relatives of clients?
Clients	Is the test acceptable to clients? Does the test cause stress or test anxiety? Does the client recognize the relevance of the test?
Professionality	Does the test look professional?
Face validity	Does the system appear valid? On the surface, does it measure what it is supposed to measure?
Portability	
Clarity of required components	Is it easy to handle in terms of the number of components required?
Transportability	Can the assessment be transferred from one location to another with little effort?
Energy and Effort	
Physical exertion	How high is the physical load for the test admin when performing the test? For example, does the client need to be physically supported?
Ease of test execution	How easy is it to perform the test? Are there a large number of tasks or extensive material that must be used?
Ease of learning	How easy is it to learn how to perform the test?
Time	
for learning test execution	How much time is required to learn how to administer and instruct clients on tests?
for evaluation	How much time is required for interpretation of test result?
for preparation	How much time is required to prepare the test in order to perform the measurement on a client?
for execution	The most obvious time factor of a measurement procedure. How much time is required to perform?
Cost	
Ongoing costs	What ongoing costs are incurred for test implementation? (software, test sheets, ...)
Required training	Are fee-based training courses required for the use of the test?
Required qualifications	Are there any special qualifications required for test administration or for interpretation of the test results? Must the scoring be performed by specially qualified persons?
Purchase costs	Which costs are calculated for the acquisition of the test, if necessary for manual and test sheets?

A focus group with occupational therapists, who have application knowledge with the NHPT, was conducted and observational studies were carried out to investigate the use of the dNHPT as a measurement tool for dexterity. The qualitative data collected was analysed using the evaluative qualitative content analysis, whereby the data was compared using the scale less, equal, better in comparison with NHPT.

To assess usability, all participants used the dNHPT exactly according to the standardized test procedure [4] and evaluated its use directly afterwards using the System Usability Scale (SUS) questionnaire. A SUS Score of 73 or more is to be rated as good and a value of 85 or more as excellent [19]. Using the convergent mixed methods approach [20], the partial results were merged and analysed and recommendations for improvement tasks for the dNHPT were derived.

3 Results

The already published results of the laboratory study show good agreement between the two measurement instruments NHPT and dNHPT using the Bland-Altman analysis and high test-retest ($ICC=0.75$; $p<0.05$) and interrater reliability ($ICC=0.76$; $p<0.05$) [15].

The investigation of clinical usefulness was carried out on the base of the subcategories of clinical utility: acceptance, costs, energy and effort, practicability and time [21]. In the focus group with four occupational therapists (mean age: 30.5 years; SD: 10.5) and the observation of four uses of the dNHPT to measure dexterity, these aspects were analysed in direct comparison with the NHPT. In each application, one participant was the test administrator and a second participant from the sample was the person being tested.

The dNHPT achieved better results than the NHPT in terms of acceptance (91% of all appraisals rated dNHPT better than NHPT) and costs (50% better and 28% of all ratings for aspect costs equal to NHPT). Acceptance is higher for the dNHPT, as its appearance is considered more professional and is therefore taken more seriously by patients from the therapists' point of view. The manufacturing costs for the dNHPT are far below the purchase costs of a standard NHPT. And the running costs are strongly influenced by the following fact: if one peg of the NHPT is, what sometimes happens in the clinical setting due to frequent use, the NHPT has to be purchased again; with the dNHPT, a missing peg can simply be reproduced using 3D printing, which significantly reduces running costs. All other aspects are rated equally to the NHPT, except the effort involved in learning the measuring instrument. 74% of overall ratings in clinical utility aspects evaluate the dNHPT equal or better compared to NHPT. Therapists see slightly more effort required to understand the function of the dNHPT and to use it.

The usability of the dNHPT is rated as good to excellent with SUS scores of 78 (for test administrators, n=4) and 85 (for tested persons, n=30) respectively. The survey with tested persons (mean age: 21.5; SD: 6.3) took place during the previous laboratory study to investigate validity and reliability [15] and was evaluated in the present study.

The partial results were used to define a series of recommendations for the further development of the dNHPT. The prototype was developed at a time when there were major supply problems on the global electronics market, so we were forced to use available components. It is possible to simplify the user interface and add more suitable components. Another recommendation includes separating the control box from the test board to allow some distance between therapist and patient and a further includes increasing the contrast between the test board and the pens (different colours). These recommendations for further improvement are to be taken into account in a further iteration of the dNHPT.

4 Discussion

This study presents the development of the digital NHPT and its comprehensive investigation of clinical utility and usability, shedding light on user perceptions and the potential benefits of such systems. The results not only provide insights into clinical utility and ease of use, but also valuable end-user perspectives that may aid in the development of future digital healthcare measurement tools.

4.1 Clinical Implications

During development of a new system, usability and practicability have to be considered in addition to functionality. Without the cooperation and acceptance of the user, the functionality of a new system may be ineffective [11].

The measurement of hand dexterity with the dNHPT follows the standardized test protocol of the NHPT. As the NHPT and its testing procedure are widely used and well known among clinicians, the use of the dNHPT as a measurement tool is equally easy to administer. There is no need to develop new descriptions for test procedures and patient instructions, as these already exist for the NHPT and also apply to the dNHPT. The advantages of the digital NHPT can improve the assessment of hand function in the therapy process and thus improve both healthcare and the rehabilitation process. The dNHPT can become a complementary tool for clinical practice.

With its automated time measurement and result presentation, the dNHPT can bring benefits in the field of research as it can save resources. The automated measurement can minimize the variability of the different testers and thus increase data quality. The high level of acceptance among all participants can bring additional benefits for clinical practice.

4.2 Limitations

Several contextual factors should be considered when interpreting our results. All results in this study reflect participants' initial experiences with the system. While this approach is appropriate for determining perceived clinical utility and ease of use, it is possible that perceptions may change over time [18]. Further studies are needed to investigate the long-term clinical benefit and ease of use of the dNHPT.

This study was conducted in a laboratory setting, which makes it possible for a study in a real clinical setting to provide additional, new information. A single researcher conducted the data collection, transcription and analysis. Although there was a high level of consistency in combining quantitative and qualitative results, the potential influence of a single researcher should be considered.

In addition, this work focused primarily on assessing the clinical utility and usability of the dNHPT. Full details of the psychometric properties of the dNHPT can be found in a previously published paper [15].

5 Conclusion

The newly developed dNHPT demonstrates an approach to digitize a measurement instrument without compromising clinical utility. The therapists responded positively to the newly developed device, which supports the assumption that there is a need for modern measuring devices in healthcare. The dNHPT has the potential to contribute to the modernization of the healthcare system and to increase the acceptance of measurement instruments.

This study provides a significant contribution to the evidence of the benefits of digitization in healthcare.

Author Statement

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all individuals included in this study. Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies and was performed in accordance with the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee.

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