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Embracing technology: professional end-users' perspectives on digital neuropsychological assessment in cognitive rehabilitation

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Abstract

Background This study aimed to explore the perspectives of healthcare professionals, both with and without previous experience of digital neuropsychological assessment (d-NPA), on the use of *supervised* d-NPA for cognitive assessment. Specifically, the study sought to: (1) understand how these professionals define d-NPA, and (2) examine the perceived benefits and limitations of its use.

Methods An online survey was administered from May to June 2021, employing qualitative analysis to summarise meaningful relationships within the data. Respondents were divided into four groups: psychologists with d-NPA experience, psychologists without d-NPA experience, other professionals with d-NPA experience, and other professionals without d-NPA experience. Descriptive statistics and frequency analyses of qualitative codes were performed, followed by logistic regression to identify significant group differences.

Results A total of 284 respondents completed the survey. Most respondents perceived d-NPA as a standardised digital cognitive assessment administered and scored via computer or tablet, suitable for both traditional face-to-face settings (with a clinician) and remote, unsupervised settings. Key benefits included efficiency, improved accuracy (with more sophisticated tests and outcome measures), and reduced workload. Concerns primarily focused on challenges with digital literacy, the suitability of digital assessments for specific patient populations, and the potential loss of qualitative observational data. Group comparisons revealed no significant differences between healthcare professionals with and without previous d-NPA experience, suggesting a shared perspective on the benefits and limitations of d-NPA.

Conclusions These findings emphasise the need to develop user-friendly digital systems through close collaboration with end-users, ensuring that digital assessments address validity concerns and tailor to patients' specific needs. Addressing these challenges can enhance the accessibility and efficacy of d-NPA for a broad clinical population.

Keywords Acquired brain injury, Clinical implementation, Cognition, Digital neuropsychology, Digital health technologies, Rehabilitation

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Background

Neuropsychological paper-and-pencil tests have long been considered the'gold standard'for assessing cognition in clinical settings [1]. However, these traditional tests may fail to detect subtle cognitive impairments and may suffer from reliability problems due to inconsistent administration or scoring errors [1, 2]. Recent technological advances have led to the development of validated digital neuropsychological tests (d-NPAs) for use in clinical and research settings, such as the Oxford Cognitive Screen-Plus (OCS-Plus; [3–5]) and Pearson's Q-interactive, which offers automated administration, scoring, and reporting of widely used traditional tests including the RBANS, WAIS-IV, and WISC-V. Digital tests contribute to a shift towards 'precision neuropsychology' by enabling more accurate identification of specific cognitive deficits that are often overlooked by traditional tests [6]. Unlike paper-based tests, d-NPA provides quantitative insights into the cognitive processes underlying a patient's final score, potentially revealing impairments even when the conventional final score is considered average [6, 7].

The growing need for robust cognitive assessment is further driven by healthcare policies aimed at improving the accessibility, efficiency and quality of care. An ageing population (with increased multimorbidity), a higher prevalence of brain injury, and a shortage of healthcare providers are placing greater demands on formal and informal care [8]. Initiatives such as the UK's NHS 10-Year Plan [9] and the Netherlands' Integral Care Agreement [10] encourage healthcare systems to adopt digital solutions. Digital tools can address limitations of traditional tests, such as lengthy test durations that contribute to long waitlists [11, 12]. Consequently, d-NPAs are increasingly being used in clinical and research settings [13–15], yet many clinicians still prefer paper-based tests [12, 16–18].

While clinicians are hesitant [12], d-NPA offer several benefits, including precise and standardised stimulus presentation and response collection [14, 19–22], automated test delivery and scoring [19, 22–24], and cost-effectiveness ([14, 23]; e.g., by reducing testing time; [25, 26]). A key factor in the successful integration of d-NPA is clinician involvement in their development and validation (i.e., a design partner; [12, 27, 28]). Engaging clinicians in a co-creation process ensures scientific rigour, maximises the impact on patient care, and minimises potential risk, resulting in d-NPA tailored to the needs of clinicians and patients [12, 28]. It is therefore important to gain a comprehensive understanding of the clinician's perspective on d-NPA.

Although some studies have speculated on the barriers to adopting digital technology (e.g., the potential limitations, e.g., [14, 18, 22, 29]), empirical research on clinicians'perspectives is still scarce. A previous study explored the potential of computers as therapeutic tools for individuals with intellectual disabilities through unstructured interviews [30]. Six key themes were identified for both clinicians and service users: access, communication, confidentiality, engagement, home practice, and the value of the therapist. Clinicians also expressed concerns about the suitability of these tools, distrust, and third-party involvement. However, the small sample size ($n = 6$; three clinical psychologists) limits the generalisability of findings, particularly given that the clinicians involved had not previously used computers for therapy within routine practice. To demonstrate the prejudice and practical merit of digital tools (e.g., computers, smartphones, or tablets; [14], it is important to explore the differences between experienced and inexperienced clinicians.

Furthermore, [19] explored the experiences and perceptions of stroke patients of a digital cognitive screener, through semi-structured interviews. Most service users preferred the digital format over paper-based tests, citing greater familiarity with digital platforms and a more interactive, less intimidating experience. Potential benefits included increased accuracy and efficiency, as well as reduced healthcare resource demands. However, service users faced challenges with attention and retention of instructions, particularly for less engaging tasks. While this study provides useful insights into stroke service users' experiences with a digital, unsupervised, cognitive screener, it does not address clinicians' perspectives on digital testing, making it essential to consider their perceived benefits and limitations of d-NPA [27].

The aim of the present study was to explore the perspectives of healthcare professionals, both with and without previous experience of d-NPA, regarding its use for *supervised* cognitive assessment. Specifically, the study sought to: (1) understand how these professionals define d-NPA, and (2) explore the perceived benefits and limitations of its use.

Methods

Participants

In the Netherlands, respondents were recruited through convenience sampling. The survey link was distributed via the Centre of Excellence in Rehabilitation Medicine Utrecht (KCRU) website, where it was listed alongside other research projects, and was also shared through relevant professional associations (e.g., those for occupational therapy, rehabilitation medicine, and speech and language therapy) as well as through personal networks on email and social media (e.g., LinkedIn and Twitter/X). Eligible respondents included professionals involved

in cognitive rehabilitation, such as occupational therapists, clinical (neuro)psychologists, and rehabilitation physicians.

Data were collected between May and June 2021, resulting in 344 respondents. These respondents represented a wide range of disciplines, spanning from assistant psychologists (four years of training: Dutch master's degree) to clinical (neuro)psychologists (10 years of training: Dutch doctorate), as well as professionals from fields such as occupational therapy, rehabilitation medicine, nursing, physiotherapy, psychodiagnostics, and research, among others. The Ethics Committee of De Hoogstraat Rehabilitation determined that this study did not require formal ethical approval under the Medical Research Involving Human Subjects Act. The research protocol adhered to the ethical principles outlined in the Declaration of Helsinki.

Procedure and survey design

The survey was created using Qualtrics software (https://www.qualtrics.com) and consisted of 18 questions, including 13 open-ended questions. The introductory text explained the voluntary nature of participation and assured respondents of data anonymity. Proceeding to complete the survey was an indication of informed consent. Closed-ended questions gathered demographic information, such as age, profession, and sex, along with respondents' previous experience with d-NPA. Open-ended questions focused on respondents' clinical populations, experiences with d-NPA, personal definitions of d-NPA, perceived benefits and limitations, and its implementation in clinical practice.

After completing the demographic questions about respondents' profession and defining d-NPA in their own terms, respondents were presented with the following definition: *"d-NPA is a digital version of traditional paper-and-pencil tests administered on an iPad in the presence of a clinician. This approach is designed to tailor the assessment to the patients' specific needs and to help qualitative observations".* Although respondents were not explicitly instructed to consider this definition when answering the questions about benefits and limitations, it was presented to clarify the concept for respondents and to promote consistency. The questionnaire has been translated into English and is included in the appendix.

Data analysis

For the open-ended responses (i.e., regarding definitions, perceived benefits, and limitations of d-NPA), an inductive thematic analysis was employed to identify patterns within the data. Two authors (C.L.W. and M.S.) familiarised themselves with the dataset and established an initial coding scheme, which they independently piloted on approximately half of the data. The coding scheme was refined through team discussions (involving C.L.W., H.H., K.M., M.S., and T.C.W.N.) to achieve consensus on differing interpretations.

C.L.W. and M.S. then applied the finalised coding scheme independently to the full dataset using Microsoft Excel, with multiple codes assigned to responses where applicable. The intercoder reliability for each open-ended question was sufficient (definition: Holsti's reliability coefficient [CR] = 0.78; perceived benefits and limitations of d-NPA: CR = 0.72 and 0.80, respectively). Discrepancies in coding were resolved through team discussion, and adjustments were made to the final dataset. Coding schemes are included in the appendix.

Descriptive analyses were performed in R, calculating sample characteristics such as means and standard deviations. To maintain data integrity, respondents who completed less than 20% of the survey were excluded [26], resulting in a final sample of 284 respondents. Frequencies for coded responses were calculated in R, with percentage distributions computed in Microsoft Excel.

Respondents were divided into four groups based on their experience with d-NPA: psychologists with d-NPA experience, psychologists without d-NPA experience, other professionals with d-NPA experience, and other professionals without d-NPA experience. Psychologists included psychodiagnostic assistants (four years of training: Dutch bachelor's degree), assistant psychologists (four years of training: Dutch master's degree), clinical psychologists (six years of training: Dutch post-master's degree), and clinical (neuro)psychologists (10 years of training: Dutch doctorate degree). Other professionals included occupational therapists, rehabilitation physicians, nurses, researchers, and other professionals. Respondents who did not report their experience with d-NPA were excluded from further analysis.

Using SPSS, a logistic regression analysis was conducted to explore differences in the proportions of sub-themes cited among the groups. This analysis aimed to determine whether significant variation existed in the frequency of cited sub-themes across groups. The dependent variable was sub-theme citation status (coded as "cited" or "not cited"), with group membership as the independent variable (factor). A multiple comparisons correction was applied, setting the significance threshold at .002 for each open-ended question (number of tests: 26 for definitions, 26 for benefits, and 28 for limitations).

Results

Data were collected between May and June 2021, resulting in 344 respondents. Of these, 284 respondents, with a mean age of 41.2 years (SD = 10.6), completed more than 20% of the survey [31] (see Table 1 for an overview

Table 1 Overview of respondents' demographic characteristics

	N	%
Age in years (mean, SD)	41.18 (10.64)	
Sex	*232*	
Women	204	87.9
Profession (top 5)	*279*	
Occupational therapist	90	32.3
Clinical psychologist	46	16.5
Assistant psychologist	45	16.1
Rehabilitation physician	39	14.0
Clinical (neuro)psychologist	21	7.5
Other	38	13.6

Assistant psychologists (four years of training: Dutch master's degree), clinical psychologists (six years of training: Dutch post-master's degree), and clinical (neuro)psychologists (10 years of training: Dutch doctorate degree). Other professions include, but are not limited to = nurse, physiotherapist, psychodiagnostic professional, researcher

of respondents' demographic characteristics). The sample was predominantly female (71.8%), while 52 respondents (18.3%) did not disclose their sex.

Regarding professional background, 42.3% were psychologists, including 38.3% clinical psychologists, 37.5% assistant psychologists, 17.5% clinical (neuro)psychologists, and 6.7% psychodiagnostic assistants. The remaining 56.0% respondents were other professionals, including 56.6% occupational therapists, 24.5% rehabilitation physicians, 5.7% nurses, 5.0% researchers, and 5.0% other professionals. However, 1.8% respondents did not specify their profession.

In terms of previous experience with d-NPA, 25.4% respondents reported previous encounters, including attending conferences or presentations, participating in scientific research, or administering digital tests. However, 8.5% did not indicate their experience and were excluded from further analysis.

Professional end-users' definition of d-NPA

Of the 248 respondents who answered the open-ended question on the definition of d-NPA, one psychologist did not indicate their experience with d-NPA. As a result, 247 responses were analysed, including 119 other professionals without d-NPA experience, 60 psychologists without d-NPA experience, 47 psychologists with experience in d-NPA, and 21 other professionals with d-NPA experience.

Analysis of the responses identified five main themes: technology, setting, test materials, results, and administration (see Table 2). The majority of respondents defined d-NPA in terms of technology, with digital tools being the most frequently mentioned aspect ($n = 314$). Specifically, computers ($n = 107$) and tablets ($n = 59$) were the most cited tools, followed by unspecified (general) digital media ($n = 16$), screens ($n = 8$), and devices ($n = 7$). Virtual reality ($n = 4$) and smartphones ($n = 3$) were mentioned less frequently. A key feature of d-NPA was the transition from traditional paper-based methods to digital cognitive assessment, particularly through digitised ($n = 87$) and online tests ($n = 23$).

The assessment setting also emerged as a defining factor ($n = 70$). Some respondents described d-NPA as a remote assessment method ($n = 35$), with a small number explicitly mentioning video calls ($n = 5$), while others highlighted its use in face-to-face settings ($n = 30$).

Table 2 Five main themes in the responses regarding the definition of d-NPA

Theme	Description	Illustrative quotes
Technology	Use of digital tools (e.g., computers, tablets, smartphones, screens) for testing	MD d-NPA: NPA no longer with paper-and-pencil, but via a tablet MD d-NPA: Digital execution of NPA
Setting	Testing conducted in both conventional and remote settings	NP d-NPA: Assessment in which the presence, supervision, and instruction of an examiner is still required CP d-NPA: Via video calling
Test materials	Shifting to digital documents, digitising existing tests, developing new tests	AP d-NPA: NPA where the test material is performed with pen-and-paper as little as possible CP no d-NPA: Modernising current diagnostic tools
Results	Digital result processing, d-NPA standardisation (automated testing), result interpretation, integration with electronic patient records	OT d-NPA: If tests are standardised, a final score will be automatically generated OT d-NPA: An initial digital interpretation of raw data NP d-NPA: Interpretation remains with neuropsychologist
Administration	Extent of d-NPA digitisation and psychometric properties	CP d-NPA: NPA consists entirely of digital tasks MD d-NPA: NPA… digital where possible AP d-NPA: While maintaining validity and reliability

AP d-NPA Assistant psychologist with d-NPA experience, *CP d-NPA* Clinical psychologist with d-NPA experience, *CP no d-NPA* Clinical psychologist without d-NPA experience, *MD d-NPA* Rehabilitation physician with d-NPA experience, *NP d-NPA* Clinical (neuro)psychologist with d-NPA experience, *OT d-NPA* Occupational therapist without d-NPA experience

In terms of test materials, respondents often described d-NPA as replacing paper-and-pencil formats with digital alternatives ($n = 27$). Some highlighted the digitisation of existing tests ($n = 21$), while others referred to the development of new digital tests ($n = 4$). Additionally, questionnaires were identified as a component of d-NPA ($n = 13$).

Processing and utilisation of results were also key aspects ($n = 62$). Respondents highlighted digital processing of results ($n = 21$) and automated test administration and scoring (i.e., standardisation; $n = 20$). Time efficiency was specifically mentioned ($n = 12$). Respondents also mentioned interpretation of results ($n = 6$)—whether digital ($n = 4$) or manual ($n = 2$), and integration of results into electronic patient records ($n = 4$).

Finally, test administration emerged as another core theme ($n = 26$). The degree of digitisation was mentioned, with some respondents referring to partially digitised administration ($n = 11$), while others described a fully digital approach ($n = 11$). A small number mentioned psychometric properties ($n = 4$), including reliability and validity considerations.

No significant differences were observed between the groups (psychologists with and without d-NPA experience, and other professionals with and without d-NPA experience; see Fig. 1 and Table 3.

Perceived benefits of d-NPA

Of the 209 respondents who answered the open-ended question about the perceived benefits of d-NPA, 6.2% of

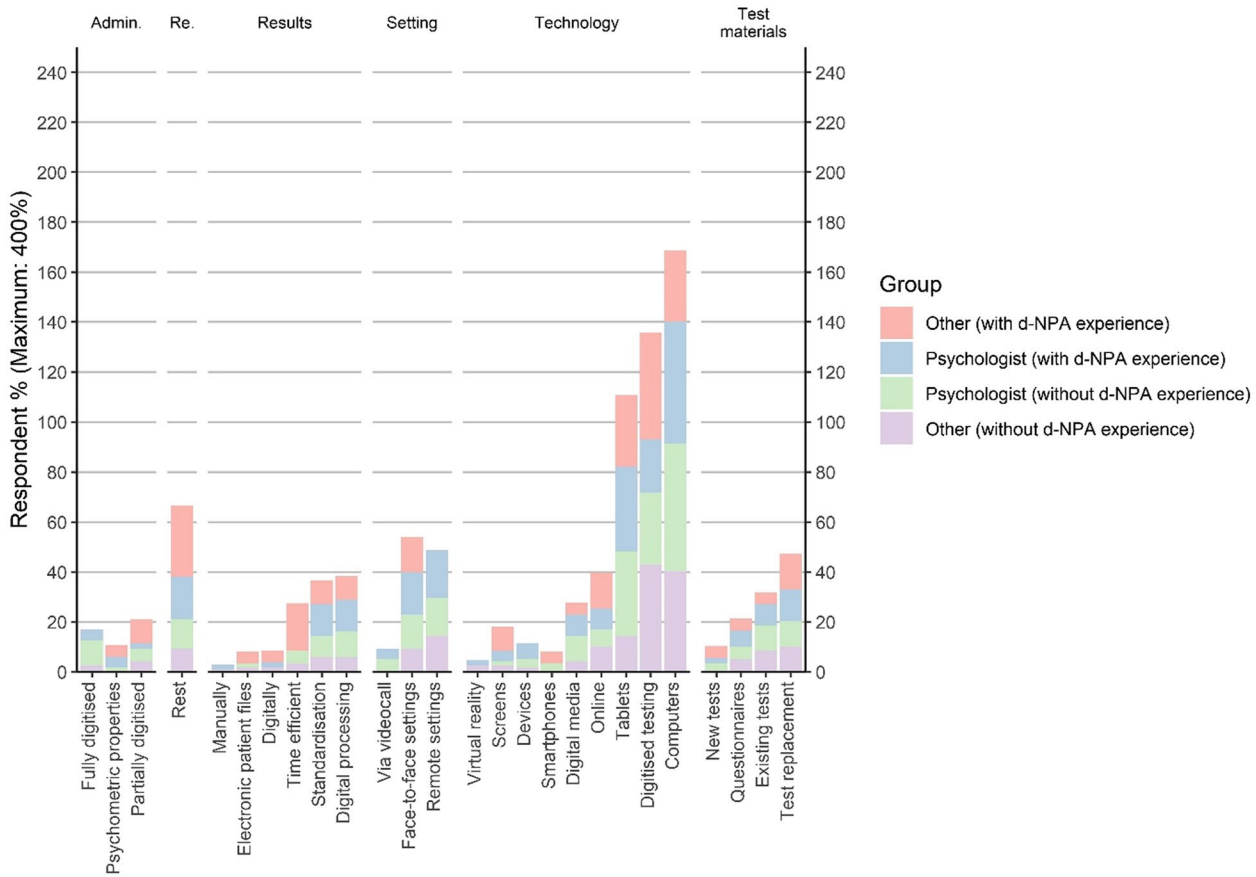

Fig. 1 Professional end-users' definitions of d-NPA: categorised by experience, group, and key themes. The faceted bar chart presents the themes identified by the authors in order to gain insight into the professional end-users' definition of d-NPA (top of the chart). The x-axis presents the sub-themes, while the y-axis indicates the percentage of respondents who mentioned each specific sub-theme. The four groups are represented by colour-coded bars, ordered by group number. For example, other professionals without d-NPA experience (in purple) represent the largest group ($n = 119$), while other professionals with d-NPA experience (in red) represent the smallest group ($n = 21$). The chart includes four groups, and each respondent mentioned at least one sub-theme within their group, resulting in a cumulative percentage of 100%. The total percentage on the y-axis is therefore 400%. For example, 50.9% of psychologists without d-NPA experience, 48.9% of psychologists with d-NPA experience, 40.3% of other professionals without d-NPA experience, and 28.6% of other professionals with d-NPA experience mentioned computers, totalling 168.7%. Abbreviations: Re. = Rest

Table 3 Chi-square test results for sub-theme citation status across groups (i.e., psychologists with and without d-NPA experience, and other professionals with and without d-NPA experience) in a logistic regression analysis

(Sub)Themes	Chi-Square	df	Sig.
Technology			
Computers	4.322	3	.229
Tablets	12.458	3	.006
Digital media	2.702	3	.440
Devices	2.974	3	.396
Virtual reality	2.087	3	.554
Smartphones	5.592	3	.133
Screens	2.656	3	.448
Digitised testing	8.919	3	.030
Online	1.146	3	.766
Setting			
Remote settings	6.443	3	.092
Via video call	7.253	3	.064
Face-to-face settings	2.152	3	.542
Test materials			
Test replacement	.504	3	.918
Existing tests	.644	3	.886
New tests	4.900	3	.179
Questionnaires	.137	3	.987
Results			
Digital processing	2.357	3	.502
Standardisation	2.114	3	.549
Digitally	2.199	3	.532
Manually	1.161	3	.762
Electronic patient files	1.786	3	.618
Time efficient	9.870	3	.020
Administration			
Fully digitised	5.861	3	.119
Partially digitised	1.775	3	.620
Psychometric properties	5.368	3	.147
Rest	5.851	3	.119

$P < .002$

responses were excluded due to insufficient responses (i.e., does not answer the question), unintelligible responses (e.g., single-letter responses), or' don't know' responses. In addition, a further 13 respondents—six other professionals, five psychologists and two professionals who did not specify their profession—were excluded because they did not indicate their d-NPA experience status. The final analysis included 183 responses: 79 other professionals without d-NPA experience, 51 psychologists without d-NPA experience, 33 psychologists with d-NPA experience, and 20 other professionals with d-NPA experience.

Thematic analysis identified five key benefits: efficiency, results, advances in assessment, future potential, and task features (see Table 4). Efficiency was the most frequently mentioned benefit ($n = 144$), with respondents describing digital tools as streamlining assessments, and reducing time and administrative burden. Automated scoring and analysis were particularly valued for improving time efficiency ($n = 58$), while instant data management and collection were seen as added value (i.e., time processing; $n = 48$). Some respondents highlighted that d-NPA reduced clinicians' workload ($n = 25$) and was perceived as less burdensome for both clinicians and patients (i.e., end-users; $n = 9$). Finally, a few respondents specifically mentioned the term 'efficiency' ($n = 4$).

Another frequently mentioned benefit was related to results, which were discussed 89 times. Respondents highlighted that automation contributes to a reduction in human error and variability, thereby enhancing the measurement objectivity of scores ($n = 29$). The ease of use of automated scoring systems was valued ($n = 25$), as was the adoption of digital processing methods ($n = 23$). Some respondents noted that digital assessment enables more efficient sharing of results ($n = 6$) and improved result interpretation ($n = 6$).

Advancements in assessment methods were mentioned 80 times. Respondents recognised the contemporary relevance of d-NPA ($n = 17$) and its alignment with modern technology and the digital literacy of the current population ($n = 12$). Some respondents noted its role in promoting patient-centred care ($n = 8$) and its particular utility for younger populations ($n = 8$). Further benefits included standardised test administration ($n = 14$), improved understanding of cognitive processes ($n = 9$), enhanced reliability ($n = 6$), and improved clinical norms ($n = 6$).

The future potential of d-NPA was another recurring theme, mentioned 48 times. Many respondents believed d-NPA could support the development of more sophisticated assessment tasks and outcome measures (i.e., assessment enhancement; $n = 41$), while some suggested it could be useful for data curation in future research (i.e., facilitating research; $n = 9$).

Task features were mentioned 41 times, with environmental sustainability emerging as a key advantage ($n = 12$). Respondents also highlighted the adaptability of d-NPA for personalised assessment, particularly in the context of adaptive testing and accessibility improvements ($n = 10$). Other operational benefits included faster and easier administration ($n = 7$), remote assessment capabilities ($n = 7$), and the portability of digital tools ($n = 3$).

No significant differences were observed between the groups (psychologists with and without d-NPA experience

Table 4 Five key benefits from the responses regarding the benefits of d-NPA

Theme	Description	Illustrative quotes
Efficiency	Streamline processes, reduce workload and minimise the burden on end users	AP d-NPA: Results are processed immediately AP d-NPA: Time savings through easier scoring and norming OT no d-NPA: Data could be stored in the patient file immediately NP d-NPA: No hassle with scanning…no unnecessary paperwork RN no d-NPA: Less burden for the patient, conducting the NPA in a familiar environment can be more comfortable for them
Results	Increase objectivity, automate scoring and improve interpretation and sharing of results	CP d-NPA: More precise measurements OT no d-NPA: Less interpretation perhaps of the person 'checking'
Advances in assessment	Align with digital trends, enhance patient-centred care and support standardisation, cognitive insight and reliability	CP no d-NPA: It aligns with the daily practice where people frequently work on screens MD d-NPA: Provides more options in the case of motor-impaired rehabilitants MD d-NPA: More systematic CP d-NPA: More insight into the process rather than the result
Future potential	Potential for advanced testing, improved outcome measures and broader d-NPA applications	AP d-NPA: Development of more sensitive outcome measures OT no d-NPA: The possibilities are endless NP d-NPA: Building an anonymous database of test results for norm groups and research MD d-NPA: Making data easier to use for research
Task features	Adaptability, accessibility, environmental benefits, ease of use, remote testing capabilities	AP d-NPA: Less paper OT/researcher no d-NPA: Enlarge font sizes AP d-NPA: Speed MD no d-NPA: Easier to administer OT no d-NPA: Added value is if people can complete it at home

AP d-NPA Assistant psychologist with d-NPA experience, *CP no d-NPA* Clinical psychologist without d-NPA experience, *CP d-NPA* Clinical psychologist with d-NPA experience, *MD d-NPA* Rehabilitation physician with d-NPA experience, *NP d-NPA* Clinical (neuro)psychologist with d-NPA experience, *OT d-NPA* Occupational therapist with d-NPA experience, *RN no d-NPA* Registered nurse without d-NPA experience

and other professionals with and without d-NPA experience; see Fig. 2 and Table 5.

Perceived limitations of d-NPA

Of the 240 respondents who answered the open-ended question on the perceived limitations of d-NPA, 11.3% of responses were excluded due to insufficient responses, unintelligible answers, or "don't know" responses. As a result, 213 responses were analysed, including 102 other professionals without d-NPA experience, 55 psychologists without d-NPA experience, 39 psychologists with d-NPA experience, and 17 other professionals with d-NPA experience.

Four key themes emerged from the analysis: user experience, assessment integrity, engagement, and technical issues (see Table 6). The most frequently cited theme was user experience, mentioned 139 times, with digital literacy being a notable concern ($n = 73$), particularly among older populations. Many respondents expressed concerns that a lack of digital skills could negatively affect performance ($n = 20$). Some also questioned the suitability of d-NPA for diverse clinical populations, particularly for older patients and those with neurological conditions such as brain injury or dementia ($n = 21$). Additional concerns included the impact of visual impairments, motor difficulties, and general apprehension towards digital tools. Concerns were also raised about the physical demands ($n = 12$) and cognitive load ($n = 8$), as they could negatively affect concentration and test performance ($n = 5$).

Assessment integrity was another widely discussed theme, mentioned 131 times. Some respondents questioned the rigidity of standardised instructions and the difficulty in tailoring tests to individual patient needs ($n = 29$). Others raised concerns about more general diagnostics ($n = 17$), including the risk of over-testing and touchscreen device accuracy. Concerns were raised about reliability ($n = 7$), in particular the relevance of clinical norms used in digital tests ($n = 18$), applying traditional paper-and-pencil norms to digital tests. Issues of validity were raised ($n = 11$), particularly construct validity ($n = 15$), with respondents highlighting that digital skills or task comprehension could influence test scores. In addition, the ecological validity of the d-NPA was questioned ($n = 10$). Moreover, issues were raised regarding remote testing ($n = 4$), particularly the risk of unqualified administration or insufficient supervision, which could compromise the assessment due

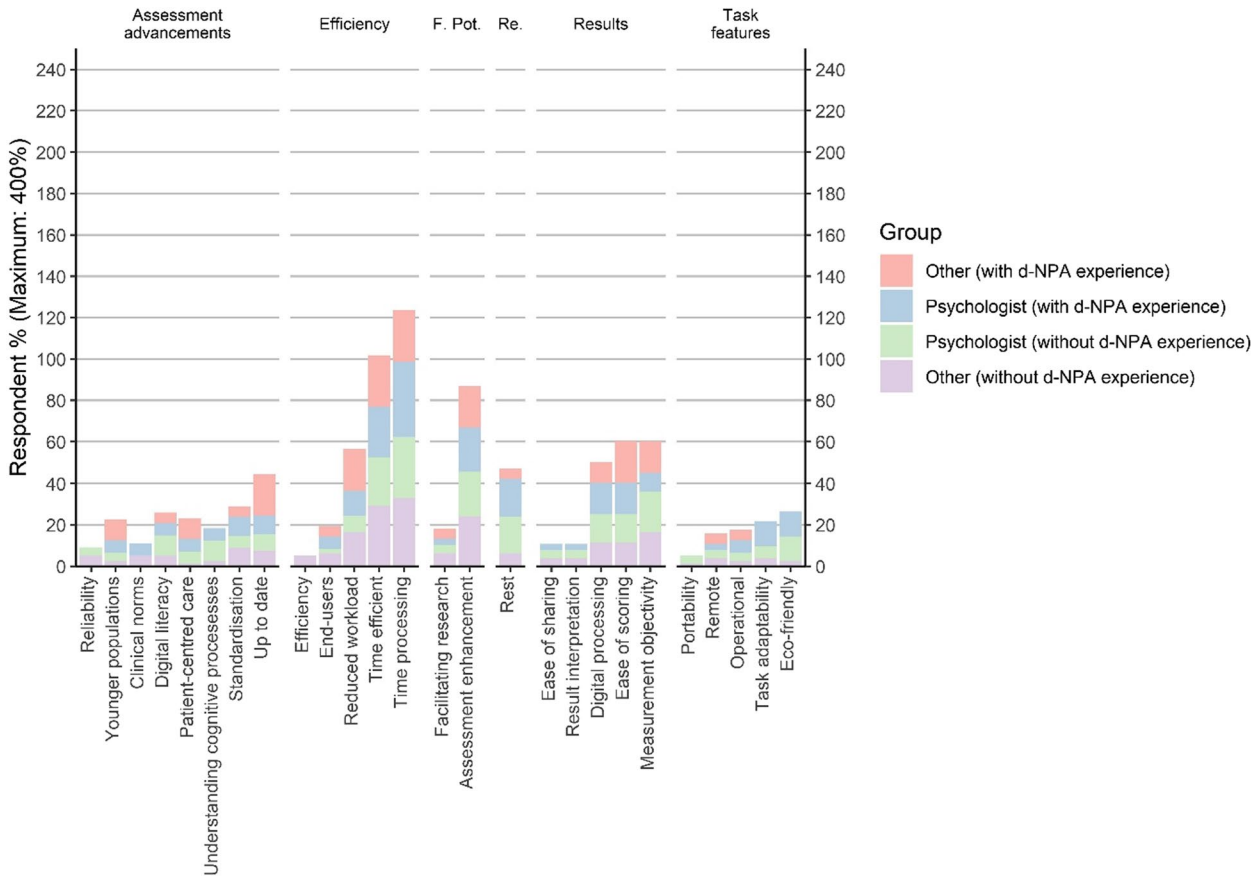

Fig. 2 Perceived Benefits of d-NPA by Professional End-Users: categorised by experience, group, and key themes. The faceted bar chart presents the themes identified by the authors as reflecting the perspectives of professional end-users' on the benefits of d-NPA (top of the chart). The x-axis presents the sub-themes, while the y-axis indicates the percentage of respondents who mentioned each specific sub-theme. The four groups are represented by colour-coded bars, ordered by group number. For example, other professionals without d-NPA experience (in purple) represent the largest group ($n = 79$), while other professionals with d-NPA experience (in red) represent the smallest group ($n = 20$). The chart includes four groups, and each respondent mentioned at least one sub-theme within their group, resulting in a cumulative percentage of 100%. The total percentage on the y-axis is therefore 400%. For example, 36.4% of psychologists with d-NPA experience, 32.9% of other professionals without d-NPA experience, 29.4% of psychologists without d-NPA experience, and 25% of other professionals with d-NPA experience mentioned time processing, totalling 177.8%. Abbreviations: F. Pot. = Future potential, Re. = Rest

to the lack of an examiner's presence ($n = 14$). Finally, concerns were raised about the overall quality of the assessment ($n = 6$).

Concerns regarding engagement were mentioned 131 times, particularly the potential loss of behavioural observations ($n = 40$). Respondents worried that important qualitative aspects of task performance might be missed, including task execution ($n = 15$), the patient's psychophysiological state ($n = 6$), and meaningful patient interactions ($n = 6$). Additionally, there were concerns about reduced patient-examiner interaction ($n = 20$) and a diminished experience with clinicians. The overall qualitative assessment was also questioned ($n = 5$). Finally, respondents expressed concerns about the over-reliance on formal test scores, which they felt could undermine clinical judgment ($n = 27$) and lead to the misinterpretation of results ($n = 12$).

Technical issues were raised 32 times, with device functionality ($n = 18$) and data security ($n = 8$) being key concerns. The financial implications of digital testing, including the costs of devices and software maintenance, were also noted ($n = 6$).

No significant group differences were observed (see Fig. 3 and Table 7).

Discussion

The present study explored the perspectives of *supervised* d-NPA, focusing on both experienced and inexperienced d-NPA professionals. By gaining insight into how these professionals define d-NPA and exploring perceived

Table 5 Chi-square test results for sub-theme citation status across groups (i.e., psychologists with and without d-NPA experience, and other professionals with and without d-NPA experience) in a logistic regression analysis

(Sub)Theme	Chi-Square	df	Sig.
Efficiency			
Time processing	.935	3	.817
Time efficient	.613	3	.893
Reduced workload	2.864	3	.413
End-users	1.620	3	.655
Efficiency	5.031	3	.170
Results			
Measurement objectivity	1.842	3	.606
Ease of scoring	1.032	3	.793
Digital processing	.480	3	.923
Ease of sharing	.883	3	.830
Result interpretation	.883	3	.830
Assessment advancements			
Up to date	2.534	3	.469
Digital literacy	1.179	3	.758
Patient-centred care	4.087	3	.252
Younger populations	2.103	3	.551
Standardisation	.717	3	.869
Understanding cognitive processes	4.642	3	.200
Reliability	3.008	3	.390
Clinical norms	4.706	3	.195
Prospects			
Assessment enhancement	.237	3	.971
Facilitating research	.716	3	.870
Task features			
Eco-friendly	7.881	3	.049
Adaptability	4.186	3	.242
Operational	.859	3	.835
Remote	.131	3	.988
Portability	2.020	3	.568
Rest	6.378	3	.095

$P < .002$

benefits and limitations, this study provides valuable insights into the challenges and opportunities associated with the adoption of d-NPA. The sample included 120 psychologists and 159 other professionals, including occupational therapists, rehabilitation physicians, nurses and researchers.

Defining d-NPA

Respondents generally defined d-NPA as standardised digital cognitive assessments administered and scored via a computer or tablet, applicable in both traditional face-to-face settings (with a clinician) and remote, unsupervised settings. This aligns with previous research [14, 19–22] as well as current clinical practice, in which NPA is increasingly digitised and used in both remote and face-to-face settings [27].

Most respondents perceived d-NPA as digitised versions of traditional test batteries rather than new, dedicated, experimental tests. Several traditional paper-and-pencil tests have been digitised ranging from shortened neuropsychological assessments (NPA) to screeners, including the Emma Toolbox [32] and the Oxford Cognitive Screen-Plus (OCS-Plus; [3]). Conversely, other digital tests are new, dedicated, experimental tests derived from cognitive neuroscience, such as the Cambridge Neuropsychological Test Automated Battery (CANTAB). Notably, few respondents addressed the degree of digitisation—whether partial or complete—highlighting a lack of clarity on the level of digital integration. Therefore, clinicians should apply their clinical judgement when determining the suitability of digital assessments for individual patients, particularly considering low cognitive capacity and digital literacy [33].

Perceived benefits of d-NPA

Respondents highlighted increased efficiency as the primary benefit of d-NPA (similar to [19, 21, 27]. This was largely attributed to the streamlining of administration, scoring, and interpretation through digital tools. Such tools markedly diminish the time needed for administration in comparison to traditional paper-and-pencil test batteries [25, 26]. To illustrate, the CANTAB can be completed in approximately two hours [34], the Emma Toolbox in approximately 75 min [32], and the OCS-Plus in approximately 25 min [25].

Furthermore, respondents mentioned the enhanced accuracy and objectivity afforded by digital tools, enabling highly detailed data collection [35]. They recognised the opportunities to develop novel outcome measures capable of identifying subtle cognitive impairments [35], contributing to the growing field of 'precision neuropsychology' [6].

Moreover, respondents perceived that d-NPA could alleviate clinicians' workloads, such as reducing their time investment (similar to [11, 12, 27]), aligning with healthcare policies aimed at improving accessibility, efficiency, and quality of care, such as the UK's NHS 10-Year Plan [9] and the Netherlands' Integral Care Agreement [10]. Consequently, d-NPA may offer a promising solution to balance the need for robust cognitive assessment with time constraints and the shortage of healthcare providers.

Respondents also acknowledged that patients are increasingly familiar with digital platforms [27]. Indeed, a study across multiple countries, including Australia (mean age =64.8 years), the Netherlands (mean age

Table 6 Four key themes from the responses regarding the limitations of d-NPA

Theme	Description	Illustrative quotes
User experience	Concerns about patients' digital literacy, particularly among older individuals, and the impact of neurological impairments on digital testing. Cognitive and physical demands may affect performance	OT/lecturer no d-NPA: Clients lacking experience with the digital world may perform poorly, but this does not necessarily reflect their cognitive functioning OT d-NPA: People with visual problems or motor impairments score worse than with paper-and-pencil MD d-NPA: Overstimulation from screen use AP d-NPA: More intense than paper-and-pencil testing
Assessment integrity	Concerns about standardised instructions limiting flexibility, diagnostic inaccuracies and risks associated with unqualified administration. Questions about test reliability, validity and the impact of remote testing	OT no d-NPA: Everything is digital, including the instructions, which means the pace cannot be adapted to the patient OT no d-NPA: External assistance OT no d-NPA: Can give a distorted picture due to not knowing how to use the computer, rather than the task itself CP no d-NPA: If a task appears to be poorly understood, it is seen as flawed, where the cognitive function may be intact but the understanding is simply inadequate OT no d-NPA: Link to daily functioning may be more distant CP no d-NPA: An unskilled person might be assigned to conduct it, which could result in lower quality NP no d-NPA: Insufficient intervention by the test leader
Engagement	Concerns about loss of behavioural observations, reduced patient-examiner interaction and overall qualitative assessment. Over-reliance on test scores could undermine clinical judgement and lead to misinterpretation of results	CP no d-NPA: Missing the observation of strategy CP no d-NPA: Fatigue perhaps less apparent AP no d-NPA: No interaction with [assistant] psychologist, but constant staring at screen AP d-NPA: Loss of human touch AP no d-NPA: Digitalisation... leaves little room for, e.g., qualitative examination Clinical linguist no d-NPA: That the clinical view is no longer used because 'everything goes digital' anyway MD no d-NPA: Perhaps drawing conclusions too soon
Technical issues	Concerns about device functionality, data security and cost	AP no d-NPA: Computer inoperative, iPad empty or untraceable

AP d-NPA Assistant psychologist with d-NPA experience, *CP d-NPA* Clinical psychologist with d-NPA experience, *CP no d-NPA* Clinical psychologist without d-NPA experience, *MD d-NPA* Rehabilitation physician with d-NPA experience, *NP d-NPA* Clinical (neuro)psychologist with d-NPA experience, *OT d-NPA* Occupational therapist with d-NPA experience

=63.4 years), and the UK (mean age =66.8 years), revealed that most patients with Motor Neuron Disease had internet access (95.6%) and frequently used digital devices such as computers, smartphones, and tablets (93.1%; [36]).

Perceived limitations of d-NPA

Despite the perceived benefits, respondents highlighted several limitations, with the primary concern being the adverse impact of digital literacy on test performance, particularly in older adults (similar to [37–39]). Concerns were raised that test performance may reflect a patient's digital literacy rather than the underlying brain function the test is designed to measure (similar to [14, 20, 23, 40]). Consistent with this concern raised by respondents, research has indeed demonstrated that cognitive performance on digital assessments is positively correlated with frequent computer use [41] and negatively correlated with low computer confidence [38].

In contrast, other studies reported that familiarity with tablets did not negatively affect test performance across various clinical populations, including healthy aging individuals (mean age =66.8 years; [42]), stroke patients (mean age =54.0 years; [19]), and individuals with traumatic brain injuries (mean age =46.5 years; [19]). Therefore, clinicians should consider the frequency of computer use, particularly in older individuals, and ensure that the testing platform aligns with the patient's comfort level. Offering a choice for traditional paper-and-pencil assessments alongside d-NPA may therefore be beneficial, which was also proposed by [27].

The suitability of d-NPA for various clinical populations was further scrutinised (similar to [30], particularly for older adults and individuals with neurological conditions such as brain injury or major neurocognitive disorder. The respondent's concern indeed aligns with research studies demonstrating that stroke patients can have challenges in attending to, understanding, and retaining instructions during digital cognitive screenings [27]. Clinicians should be encouraged to clarify or repeat instructions as necessary [27]. Nonetheless, computerised cognitive assessments have been demonstrated to be effective and valuable even as early as day four post-stroke [43].

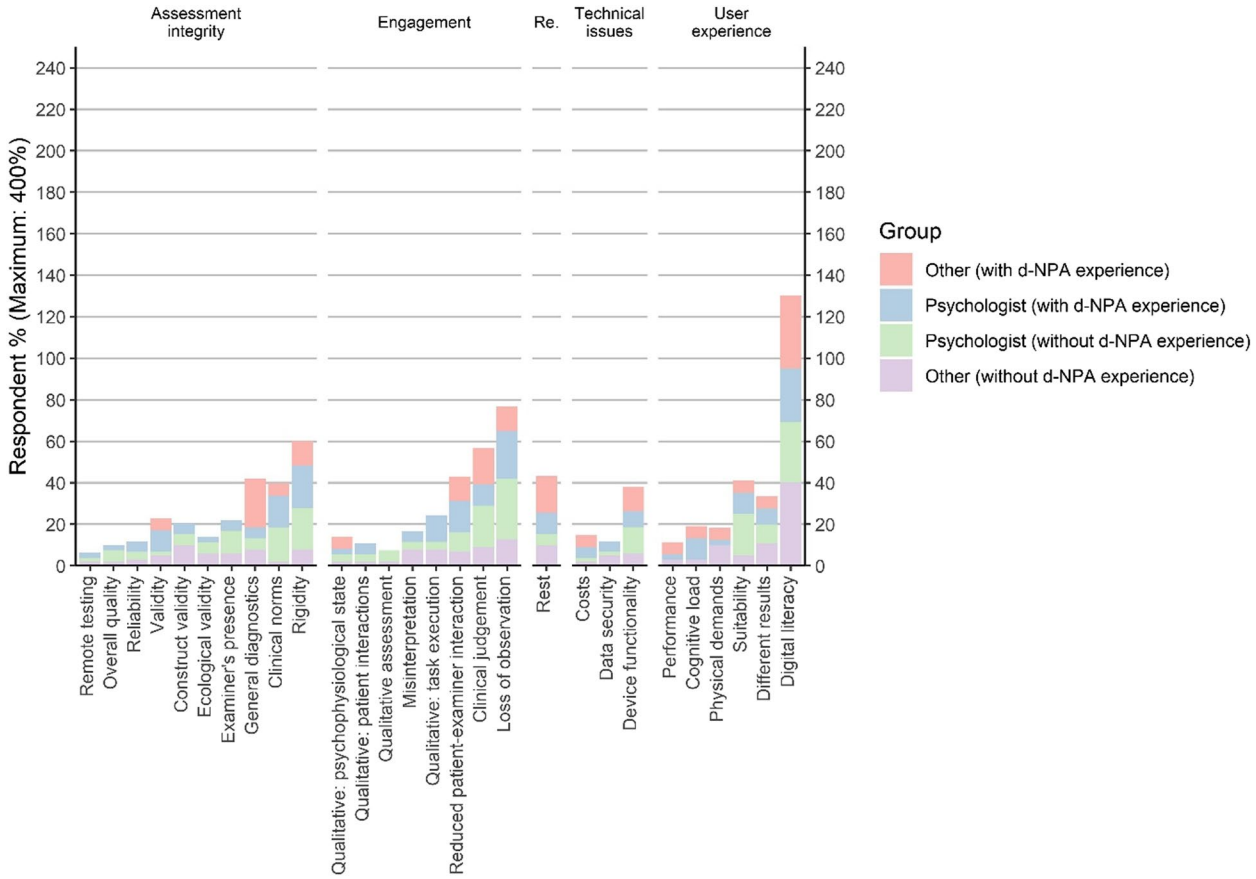

Fig. 3 Perceived Limitations of d-NPA by Professional End-Users: categorised by experience, group, and key themes. The faceted bar chart presents the themes identified by the authors as reflecting the perspectives of professional end-users' on the limitations of d-NPA (top of the chart). The x-axis presents the sub-themes, while the y-axis indicates the percentage of respondents who mentioned each specific sub-theme. The four groups are represented by colour-coded bars, ordered by group number. For example, other professionals without d-NPA experience (in purple) represent the largest group ($n = 102$), while other professionals with d-NPA experience (in red) represent the smallest group ($n = 17$). The chart includes four groups, and each respondent mentioned at least one sub-theme within their group, resulting in a cumulative percentage of 100%. The total percentage on the y-axis is therefore 400%. For example, 40.2% of other professionals without d-NPA experience, 35.3% of other professionals with d-NPA experience, 29.1% of psychologists without d-NPA experience, and 25.6% of psychologists with d-NPA experience mentioned digital literacy, totalling 130.2%. Abbreviations: Re. = Rest

Finally, concerns were raised about the potential loss of qualitative data during digital assessments, particularly behavioural observations crucial for interpreting cognitive and neuropsychological evaluations [23, 27]. Qualitative observations conducted before, during, and after test sessions are essential for interpreting test scores [44]. Current guidelines emphasise that clinicians must integrate multiple sources of relevant and reliable information, including behavioural observations (e.g., the Cognition in Daily Life scale; [45]), to ensure accurate test interpretation [23, 46]).

Overall, the study revealed a broad consensus among experienced and inexperienced professional end-users on the definition, benefits, and limitations of d-NPA. There were no significant differences in perspectives based on previous experience with d-NPA, indicating that concerns on suitability and validity are widely recognised among clinicians. This uniformity highlights that whilst d-NPA hold considerable potential, professional end-users share apprehensions.

Strengths and limitations of the study

A major strength of the present study is the extensive engagement of respondents, with a large sample size of 284 respondents. The inclusion of professional end-users directly involved in cognitive rehabilitation enhances the relevance of the findings to clinical practice and improves both the representativeness and generalisability of the results by including a wide range of disciplines. The involvement of end-users in the development and

Table 7 Chi-square test results for sub-theme citation status across groups (i.e., psychologists with and without d-NPA experience, and other professionals with and without d-NPA experience) in a logistic regression analysis

(Sub)Theme	Chi-Square	df	Sig.
User experience			
Digital literacy	3.585	3	.310
Performance (negative)	.649	3	.885
Suitability	8.812	3	.032
Physical demands	9.104	3	.028
Cognitive load	6.922	3	.074
Performance	2.705	3	.439
Assessment integrity			
Inflexibility	6.488	3	.090
General diagnostics	4.863	3	.182
Reliability	1.002	3	.801
Clinical norms	13.584	3	.004
Validity	3.315	3	.346
Construct validity	3.307	3	.347
Ecological validity	1.846	3	.605
Overall quality	3.290	3	.349
Remote testing	.301	3	.960
Examiner's presence	3.262	3	.353
Engagement			
Behavioural observations	7.156	3	.067
Task execution	4.666	3	1.98
Psychophysiological state	.885	3	.829
Patient interactions	1.495	3	.683
Patient-examiner interaction	2.355	3	.502
Overall qualitative assessment	1.869	3	.600
Clinical judgement	4.395	3	.222
Misinterpretation	2.636	3	.451
Technical issues			
Device functionality	2.352	3	.503
Data security	1.946	3	.584
Costs	1.596	3	.660
Rest	2.326	3	.507

$P < .002$

evaluation of new medical technologies is increasingly recognised as important [19, 27, 47, 48].

A number of limitations should be considered when interpreting these findings. A primary concern is the use of convenience sampling, which may have resulted in a sample that may not be fully representative of all professionals working in cognitive rehabilitation in the Netherlands. The sample may be biased towards individuals with stronger opinions or greater familiarity with d-NPA, limiting the generalisability of the findings to the wider professional population. Although this may limit representativeness, the survey prompted respondents to consider both the benefits and limitations of d-NPA. Importantly, by avoiding quantification of respondents' views (e.g., numerical scores), the study encouraged more open-ended, reflective responses, supporting a broader and more nuanced range of perspectives. Moreover, data saturation was confirmed during the coding process, which was applied to responses from approximately half of the participants, with subsequent responses providing no new insights. Analysis was extended to the full sample to ensure comprehensive data saturation [28].

The timing of the survey is also a potential limitation, as it coincided with the COVID-19 pandemic and the subsequent lockdown in the Netherlands, as documented in the official government Coronavirus timeline [49]. This timing may have led to confusion among respondents regarding the concept of d-NPA. Furthermore, there is a possibility that the survey may have overemphasised teleneuropsychology. However, it is important to note that remote testing was not a prevalent theme in the survey. Furthermore, respondents were provided with a clear definition of d-NPA, which included an explanation of the role of clinician supervision.

Recommendations for researchers and test developers

Given clinicians' concerns on the extent to which digital tests accurately reflect cognitive processes rather than digital literacy, future studies validating new digital tests should investigate the impact of varying digital literacy levels on test performance. This would help determine whether digital literacy should be considered when interpreting test scores. Psychometricians should also aim to establish normative data for diverse demographic groups based on their digital literacy levels, enabling clinicians to account for its potential effects. For example, normative data for the remote administration of the WAIS-IV-UK were still collected via face-to-face assessment [33].

Moreover, it may be important to develop evidence-based clinical guidelines that define the minimum digital literacy needed to complete a digital test in a valid manner. These guidelines will help determine who can be reliably assessed using digital tools and who may need alternative assessment methods. Quantifying the necessary digital literacy could involve identifying specific tasks or competencies that individuals should be able to perform to ensure accurate test completion (e.g., online banking).

Furthermore, in today's increasingly digital world, digital literacy may be considered a crucial skill. Digital testing may offer a more ecologically valid measure, considering that effective navigation and utilisation of digital tools and online platforms have become essential in daily life (e.g., access information, online banking, internet literacy, online communication). Therefore, it may be useful to measure a patient's digital literacy alongside other cognitive skills. Incorporating a holistic assessment (i.e.,

multidimensional measurement of cognition; see [45]) by measuring cognitive functioning at levels of activity (e.g., online banking, shopping) and participation (e.g., questionnaires), in addition to the level of impairment (e.g., [d-]NPA) could provide a more accurate estimate of a patient's cognitive capabilities [47].

Lastly, the findings highlighted the importance of developing user-friendly digital systems through close collaboration with end-users (i.e., clinicians and patients encountered in clinical practice), tailoring the test to the individual patient needs to determine optimal accessibility and usability of digital tests for a diverse clinical population (e.g., multiple task variants to avoid floor and ceiling effects; [50]). Prioritising user-friendliness enhances the feasibility of digital tests (i.e., ability to complete assessment), thereby increasing their potential for successful implementation in clinical practice. In addition, clinicians should be proficient in the chosen technology (i.e., confident in the use of digital tools and familiar with the relevant settings) to ensure professional assessment [51]. The valid use of a psychometric tool depends in part on adherence to standardised instructions. Clinicians are encouraged to practice with the technology to support professional delivery [51].

Conclusions

In conclusion, this study highlighted the perspective of clinicians on the potential benefits of the d-NPA for the assessment of cognition, but also underscored the importance of addressing concerns about its validity and tailoring the test to the individual needs of patients. By addressing these issues, digital neuropsychological testing could be made more accessible and effective for a diverse clinical population.

Abbreviations

d-NPA	Digital neuropsychological tests
NPA	Neuropsychological assessment

Supplementary Information

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Supplementary Material 1.

Supplementary Material 2.

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Authors' contributions

T.C.W.N. served as the principal investigator and, together with J.M.A.V.-M., conceptualised and designed the study. T.C.W.N. also contributed to the development of the survey content. Data analysis was performed with support from H.H., K.M., and T.C.W.N., in collaboration with C.L.W. and M.S. H.H. and C.L.W. prepared figures 1-3. C.L.W. drafted the main manuscript text, with all authors contributing to its editing and review.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The Ethics Committee of De Hoogstraat Rehabilitation determined that this study did not require formal ethical approval under the Medical Research Involving Human Subjects Act. The research protocol adhered to the ethical principles outlined in the Declaration of Helsinki. The introductory text explained the voluntary nature of participation and assured respondents of data anonymity. Proceeding to complete the survey was an indication of informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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