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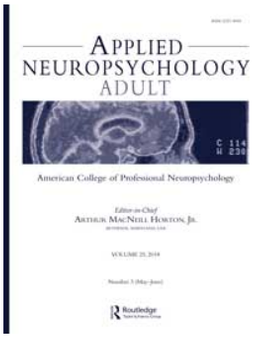

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Screening of visual perceptual disorders following acquired brain injury: A Delphi study

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ABSTRACT

Impairments in visual perception are common after acquired brain injury (ABI) and adequate assessment is crucial for diagnosis and rehabilitation. However, there is no consensus yet on how to assess these disorders after ABI. The aim of the present study was to explore what measures are considered reasonable to be part of a test battery for the screening of a broad range of mid-level and higher-order visual perceptual disorders. A Delphi method was used to collect the opinions of 28 international multidisciplinary experts in visual perception in order to achieve consensus on the content of the test battery. Seventeen experts evaluated the test battery proposed in the third and final round of the Delphi process. Consensus was achieved (94%) on a battery of 11 distinctive tests with an expected administration time of 30 minutes. The current study provides an essential step in the development of a standardized and time-efficient test battery for the screening of mid-level and higher-order visual perceptual disorders. The composed battery may improve effectiveness of clinical assessment by providing insight into potential visual deficits in little time, thereby initiating further assessment. Future studies should focus on the validation of the suggested test battery and collect normative data.

KEYWORDS

Acquired brain injury; Delphi; screening; test battery; visual perception

Almost a third of the human neocortex is thought to be involved in vision (Van Essen & Drury, 1997). It is, therefore, not surprising that acquired brain injury (ABI; e.g., stroke, brain tumor, traumatic brain injury, or neurodegenerative diseases) frequently results in visual perceptual disorders (Costa et al., 2015; Greenwald, Kapoor, & Singh, 2012; Husain & Rorden, 2003; Lincoln, 1995; K. McKenna, Cooke, Fleming, Jefferson, & Ogden, 2006; Riggs, Andrews, Roberts, & Gilewski, 2007). A variety of perceptual disorders can be differentiated, such as visual agnosias, hemispatial neglect, spatial memory disorders, constructive disorders, and disorders in movement perception. Visual perception has a major role in daily activities, for instance reading, writing and mobility. Daily functioning and employability of patients following ABI can therefore be considerably affected in case of visual disturbances (Greenwald et al., 2012; Jehkonen et al., 2000; Warren, 1993).

In order to optimize the rehabilitation process and to improve daily functioning of patients, adequate assessment of visual perceptual disorders is paramount. There are reasons to assume that a standardized screening tool for a broad range of functions may be a suitable means for an initial assessment of visual perceptual disorders in patients with ABI, rather than the administration of a comprehensive neuropsychological assessment to all patients. First, a comprehensive neuropsychological assessment is time consuming (usually requiring between two to three hours of assessment) and may not be necessary in all patients presenting for clinical evaluation. In addition, in order to interpret many cognitive measures accurately (e.g., measures to assess language functions), potential influences of visual deficits of the patient should be accounted for. Second, the great variety of possible visual disorders makes test selection difficult and often unclear. In this respect, a standardized screening tool could cover a broad range of visual perceptual functions. Third, experienced problems of patients with ABI may not always correspond to objectively assessed cognitive impairments (Edmonds et al., 2014; French, Lange, & Brickell, 2014; Lannoo et al., 1998), which may complicate or even mislead assessment and eventually diagnosis. For example, a considerable proportion of patients with ABI report

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nonspecific, visual complaints like "blurred" or "foggy" vision, reduced contrast sensitivity, or impaired adaptation to changes in light (Bulens, Meerwaldt, van der Wildt, & Keemink, 1989; De Haan, Heutink, Melis-Dankers, Brouwer, & Tucha, 2015; Zihl, 2011). Although these patients may describe their visual complaints in lower order sensory terms, such as 'blurry', the actual problem might be related to higher-order perceptual processes. Critchley (1964) already noted that patients with agnosia-like symptoms perceive contours of objects or faces as "darker, smaller and misty" or "as if there was a thin layer over it all." Based on the medical history of these patients and their self-reports of experienced problems, these patients would most likely not be referred for a neuropsychological assessment, which may confound the diagnostic process. Therefore, an initial screening could be a time-efficient solution for this issue. Fourth, a recent review on structural MRI studies revealed several eye diseases to be associated with structural changes in the visual pathways of the brain (Prins, Hanekamp, & Cornelissen, 2016) and, therefore, possibly with higher-order perceptual deficits. On these grounds, it can be argued that a standardized screening can be a useful approach for the above described cases, as the screening is not composed based on individual complaints or clinical hypotheses, but is rather composed based on the likelihood that a deficit is present in a certain population.

Several test batteries exist for the assessment of visual perceptual disorders following ABI, however, most of these batteries cover only a limited range of disorders (e.g., Visual Object and Space Perception battery (VOSP; Warrington & James, 1991), Motor-Free Visual Perception Test (MVPT; Colarusso & Hammill, 1972), focus on spatial neglect (e.g., Fordell, Bodin, Bucht, & Malm, 2011; Stone et al., 1991; Vaes et al., 2015)), may be insufficiently validated (e.g., Birmingham Object Recognition Battery [BORB]; Riddoch & Humphreys, 1993) or take too long to administer to represent a useful screening tool (e.g., Rivermead Perceptual Assessment Battery (Whiting, Lincoln, Bhavnani, & Cockburn, 1985)). The fact that most of these test batteries consist of conventional paper and pencil tests may represent another weakness, as paper and pencil tests make it impossible to measure important dynamical aspects of vision, such as motion perception, which nowadays could easily be assessed with tablet PCs or similar devices. For these reasons, there is a need for a modern standardized tool for the screening of visual perceptual disorders that: (a) covers a broad range of visual perceptual functioning, (b) takes little time to administer, (c) enables presentation of dynamical stimuli, and (d) is validated.

Several approaches have been applied in the development of tests and screening instruments for visual perceptual disorders, including theory-driven selections of tests and measures (e.g., Occupational Therapy Adult Perceptual Screening Test (Cooke, McKenna, & Fleming, 2005), Leuven Perceptual Organization Screening Test (L-POST; Torfs, Vancleef, Lafosse, Wagemans, & De Wit, 2013; Vancleef et al., 2014). Although these developments certainly have merits, there is no consensus yet on how to screen for visual perceptual disorders after ABI. In this context, a Delphi method seems to be useful in selecting suitable screening instruments. The Delphi method is a structured communication technique that is suitable for developing guidelines in areas of research where clear guidelines cannot be concluded yet from existing research (Ziglio, 1996). This technique aims to achieve consensus on a question or issue by collecting the opinions of a number of experts in the particular field (Hsu & Sandford, 2007). In the present study, an international expert panel of experienced researchers and clinicians in fields related to visual perception is composed, that is asked to complete three rounds of questionnaires in a serial manner. In the beginning of the second and third round, before completing the respective questionnaire, results of the previous round were summarized and presented to the experts. This was done in order to encourage experts to reconsider their given opinion in the light of the group results to make a conversion of opinions towards a consensus possible. The use of a Delphi method in healthcare research has become more frequent (see, for a review, Boulkedid, Abdoul, Loustau, Sibony, & Alberti, 2011) and is of particular use when empirical studies on this question or issue are scarce or have not come to an agreement yet (Hasson, Keeney, & McKenna, 2000). Advantages of a Delphi method can be deduced from its structural features. First, a classical Delphi method consists of a number of questionnaires presented to a panel of experts, with each questionnaire following-up on the previous one. The iterative character of a Delphi, and the presentation of group results of the previous round at the beginning of each round, allows the experts to modify their opinions with the purpose of reaching a group consensus (Sobaih, Ritchie, & Jones, 2012). Another strength of the method is the anonymous participation of the panel members, reducing group and/or peer pressure (Mullen, 2003; Sobaih et al., 2012). As such, the influence of authority (e.g., based on the individual's personality, age and status) on the consensus is minimized.

In the present study, we report on the application of a Delphi method to reach consensus on the content and composition of a test battery for the screening of

mid-level and higher-order visual perceptual disorders in patients with ABI. The outcome of the Delphi method may help clinicians in their decision regarding which aspects of visual perception should routinely been screened for in patients with ABI and which measures are considered appropriate. The results of such screening should offer insight into potential visual deficits and indicate domains of visual function that may require further clinical assessment.

Methods

Goal of the study

In order to provide a recommendation for a state of the art screening for visual impairments which can be used in a wide range of settings and applied to a broad range of brain-injured patients (e.g., rehabilitation centers and hospitals), we aimed to get consensus of an expert panel about a test battery with an administration time of about 30 minutes. The definition of a satisfactory level of consensus differed largely between previous Delphi studies, ranging from 55 to 100% (Powell, 2003). For the purpose of the present study using the Delphi method, we define consensus as a degree of 80% agreement between experts in the final round, which can be considered conservative.

Selection of experts

The selection of experts to form the expert panel was based on an extended literature search aiming to identify active and experienced researchers as well as on recommendations of experienced clinicians and researchers. In order to ensure a broad range of perspectives, potential international experts were recruited from several disciplines important to the field of visual perception, such as neuropsychology, (neuro-)ophthalmology, visual neuroscience and vision rehabilitation. Experts were invited if they met at least one of the following two conditions: having a postdoctoral position in the field of visual perception or having at least four years of experience in the clinical field of visual perception. Invited experts were asked to recommend other potentially suitable experts. All communication with the experts took place via online tools (Qualtrics, Provo, UT, USA, 2016).

In total, 43 experts in visual perception were invited to participate in the present study. Of all 43 experts invited, 28 agreed to participate. Thirteen experts did not reply, one expert indicated to not feel qualified for the purpose of this study and one expert rejected the invitation without further specification. All experts were asked to provide written informed consent and to fill out a questionnaire on descriptive and demographic information after confirming their participation as a panel member in this study. This Delphi consisted of three rounds of questionnaires (see following subsection on the design of the questionnaire rounds). In the first round, 21 experts completed the questionnaire (75% of the initial sample of 28 experts), six experts did not reply and one expert indicated to not feel qualified for the purpose of the study. All experts of the initial panel were invited to participate in the second round, with the exception of the one person who indicated after the first round to not feel qualified for the study. Nineteen experts completed the questionnaire of the second round (67.9% of the initial sample of 28 experts), eight experts did not reply and one expert withdrew his participation because of time constraints. Only experts who completed the second round were invited for the final third round. Seventeen experts completed the third round (60.7% of the initial sample of 28 experts), two experts did not reply. Table 1 shows the characteristics of the panel for each round. Experts participated on a voluntary basis and did not receive financial compensation for their participation. This study was approved by the Ethical Committee Psychology (ECP) affiliated to the University of Groningen, The Netherlands.

Design of the questionnaire rounds

After initial informed consent had been given for participation in the study, three rounds of questionnaires were presented to the expert panel in a serial manner. A group of six researchers (the authors of this study) agreed on the content of the rounds, composed each questionnaire and checked for comprehensibility and feasibility. Qualtrics software (Qualtrics, Provo, UT, USA, 2016) was used for the development, distribution and administration. In each round, the expert panel was provided with a link directing the experts to the online questionnaire. Experts who did not complete the questionnaire in a particular round were sent a maximum of three reminders (three weeks, six weeks, and nine weeks, respectively) after the initial invitation to that specific round. In the second and third round, experts were provided with all of the results of the previous round and were subsequently requested to complete the questionnaire of the present round. Experts were instructed to take the results of the previous round into consideration when completing the new questionnaire. In order to allow for tests using presentation of dynamical stimuli, experts were asked to provide tests that could be digitized. The experts were given the opportunity to comment on each question and to elaborate their answers when necessary. Each round took between 15–45 minutes to complete. A summary of the design of each round is presented in Table 2.

Table 1. Characteristics of the expert panel.

	Initial panel[a]	Participation on first round[b]	Participation on second round[c]	Participation on third round[d]	Participation on all rounds[e]
Experts *N*	28	21	19	17	16
Gender, male/female *N*	17/11	11/10	10/9	9/8	8/8
Academic degree/position N (%)					
Professor	13 (46.4)	9 (42.9)	6 (31.6)	5 (29.4)	5 (31.3)
PhD	11 (39.3)	8 (38.1)	9 (47.4)	9 (52.9)	8 (50.0)
MSc.	4 (14.3)	4 (19.0)	4 (21.1)	3 (17.6)	3 (18.8)
Geographic scope *N* (%)					
The Netherlands	9 (32.1)	9 (42.9)	8 (42.1)	7 (41.2)	7 (43.8)
Germany	10 (35.7)	6 (28.6)	6 (31.6)	5 (29.4)	4 (25.0)
Belgium	2 (7.1)	1 (4.8)	1 (5.3)	1 (5.9)	1 (6.3)
UK	4 (14.3)	3 (14.3)	2 (10.5)	2(11.8)	2 (12.5)
North America	2 (7.1)	1 (4.8)	1 (5.3)	1 (5.9)	1 (6.3)
Israel	1 (3.6)	1 (4.8)	1 (5.3)	1 (5.9)	1 (6.3)
Years of experience in visual perception (clinic or research)					
Median	15	15	15	15	15
Range	4–50	4–50	4–39	5–39	5–39
4–9	5	4	4	3	3
10–19	10	9	10	10	9
20–29	2	2	1	1	1
>30	6	6	4	3	3
Missing *N*[f]	5	–	–	–	–
Number of published articles in visual perception (Journal articles and books)					
Median	17	17	12	12	10
Range	0–200	0–200	0–200	0–200	0–200
0	3	3	3	2	2
1–9	6	6	6	6	6
10–19	3	2	2	2	2
20–49	4	3	4	4	3
50–99	2	2	1	1	1
>100	5	5	3	2	2
Missing *N*[f]	5	–	–	–	–

[a]Characteristics of experts who initially agreed to take part in the study.
[b]Characteristics of the experts who completed the first round.
[c]Characteristics of the experts who completed the second round.
[d]Characteristics of the experts who completed the third round.
[e]Characteristics of the experts who completed all three rounds.
[f]Missing: Frequency of experts who did not provide information concerning this question. All experts of whom these data were missing obtained at least a PhD degree.

First round

The first round was a brainstorm session aiming to collect opinions from the experts on a wide range of visual perceptual disorders and their assessment methods. This round consisted of four open-ended questions. Experts were asked which visual perceptual disorders, according to them: (1) were most common after acquired brain injury, (2) do currently not get sufficient attention in clinical practice and should be more adequately assessed, and (3) could be associated with nonspecific visual complaints, such as blurred vision. For each disorder mentioned, the experts were (4) asked for the most suitable method to assess that disorder. Experts were given the opportunity to mention multiple disorders per question. Furthermore, experts were asked for their knowledge with regard to each disorder mentioned, by indicating their self-rated level of knowledge on a 5-point scale ranging from 1 (basic) to 5 (expert).

A content analysis for qualitative data (Burnard, 1991) was carried out in order to categorize the visual perceptual disorders suggested in this first round. The categories of visual perceptual disorders were determined by agreement between three researchers (SdV, JH, FC) working in the field of visual perception. All visual perceptual disorders as mentioned by the expert panel were allocated to one of the categories. Since the answers in this round provided the basis for the succeeding rounds, answers of the first three

Table 2. Summary of the design of each Delphi round.

Round	Description of the round	Aim
1	Brainstorm session about existing visual perceptual disorders and their assessment methods.	To create a framework for the succeeding rounds.
2	Ranking of the visual perceptual disorders and their assessment methods by importance for the test battery.	To compose the content of a test battery for the assessment of mid-level and higher-order visual perceptual disorders.
3	Presentation of the 30 minutes test battery	To reach consensus about the selected tests and composition of the test battery.

questions were collapsed for the purpose of the content analysis. Lower-level visual disorders (e.g., visual field defects and diplopia) were excluded from further elaboration, given that the goal of this study was to provide the ingredients of an appropriate screening assessment regarding mid-level and higher-order visual perceptual disorders. Mid-level or higher-order visual perceptual disorders that are considered to be part of an assessment for lower level visual function (e.g., alexia) in many rehabilitation centers (e.g., Royal Dutch Visio, a rehabilitation center in The Netherlands for blind and visually impaired people) were, therefore, also excluded from further elaboration. Answers that were too unclear or unspecific to allow categorization were excluded too. Descriptive statistics were used to summarize the results for both the visual perceptual disorders and their corresponding tests. All tests suggested by more than 50% of those experts that actually mentioned the corresponding disorder during the first round, were immediately proposed to the expert panel in the second round for inclusion in the test battery, assuming consensus will be reached for the corresponding disorder. However, if the suggested test was not specific enough (e.g., only a description of variables instead of a test name or test paradigm) or if the suggested test was a test battery, measuring various aspects of functioning, instead of a single (sub)test, then, a test that could be derived from the answers of the experts was proposed to the expert panel in the next round. If this was not possible (e.g., a certain visual perceptual disorder was only considered for inclusion by one expert), no test was proposed for this specific visual disorder. For example, if a cancellation task was mentioned by more than 50% of the experts to assess neglect, but results were not conclusive on which cancellation test this should be, the researchers proposed a specific cancellation test in the second round, taking practical considerations into account (e.g., clinical utility). Tests to which less than 50% of the experts had agreed on, no test was proposed in the next round. The results of each round, i.e., descriptive statistics of all suggested disorders and tests (e.g., median ranks, mean level of knowledge), were presented to the expert panel by all means. This should help the experts to take a stand on the proposed tests in the light of all suggested disorders and tests. In this way, this preselection of tests by the researchers of this study was aimed to guide the Delphi process.

Second round

The purpose of the second round was to obtain the opinion of the expert panel about the content and composition of the test battery. The expert panel was provided with the results of the first round (organized in a way that the most often suggested visual disorders were presented first), together with a new questionnaire, consisting of three questions. The experts were (1) asked to rank the visual perceptual disorders suggested in the first round by importance for the test battery and subsequently, to indicate on a 3-point scale (agree – neutral – disagree) whether these disorders should be screened for. Thereafter, the experts were (2) asked to indicate their agreement on a 3-point scale (agree – neutral – disagree) whether they agree with a proposed test (i.e., a test suggested by more than 50% of those experts that mentioned the corresponding disorder in the first round) as being suited for the screening of the corresponding disorder. If no test could have been proposed based on the results of the first round (i.e., no test was mentioned by more than 50% of the experts), the experts were asked in the second round to rank all tests suggested during the first round per disorder with regard to their suitability to assess the corresponding disorder. If the experts disagreed with the proposed test (as suggested by more than 50% of the experts) in the second round or if ranking was not possible (e.g., only one test for the corresponding disorder was mentioned by the experts during the first round), the experts were again asked to suggest a test by means of an open-ended question. The experts were not asked to specify tests for those disorders that they did not find relevant for a screening assessment. For each test presented, the experts were asked to indicate on a 4-point scale how well they know the specific test, ranging from "very well" to "I do not know this test." The disorders mentioned in the first round that are considered to be lower-level disorders, or mid-level and higher-orders disorders that are usually part of a lower-level visual assessment were reported back to the expert panel, together with a rationale for exclusion from the present study. The experts were then (3) given the possibility to indicate their disagreement by commenting on these excluded disorders.

Responses of the second round were analyzed by means of descriptive statistics. In case experts indicated that they do not know a specific test or when they did not specify whether they are familiar with the test, their answer was excluded from analysis. To guide and facilitate the Delphi process, the researchers selected one test for each visual perceptual disorder, starting with the disorder that was considered as most important by the expert panel to include in a test battery, as indicated by median ranks. If more than one disorder has been assigned the same median rank, then the proportion of experts suggesting a disorder for inclusion in a test battery was considered as the criterion to start test selection. Subsequently, test selection for each visual

perceptual disorder was based on four arguments. First, tests were selected based on the experts' opinion, i.e., tests with highest rankings or tests most often suggested. Second, in case the experts' opinion brought forward a test that was too experimental in nature (i.e., low clinical utility), a validated test known to assess the same function was selected. Third, it was taken into account that a thorough follow-up assessment might follow a screening assessment in order to provide further insight into the possible disorder. Hence, to avoid test-retest effects, more extensive tests were spared as a possibility to use this test in its completeness for a more thorough assessment. In such case, a variant of the initially suggested test was proposed to the panel in the next round (i.e., a test that is shorter or less distributed, but that is known to assess the same function). Finally, test selection was based on its unique contribution to the test battery. For example, selection of tests based on the experts' opinion may result in some aspects of functioning that are assessed by a test already selected to be proposed for inclusion in the test battery. As such, a comparable test was chosen that was assumed to be less redundant in its contribution. A more elaborate description of these arguments can be found in Table 3. Test selection continued until a test battery was composed that took about 30 minutes to administer.

Third round

In this final round, a test battery of about 30 minutes resulting from the second round was presented to the expert panel, including the arguments on which test selection was based on (Table 3). The expert panel was asked to indicate whether they agree or disagree with the content and composition of the test battery. The level of agreement on the total test battery was determined on the basis of descriptive statistics. For the present purpose, consensus was achieved if 80% of the expert panel agreed on the test battery in the final round.

Results

First round

The responses of 21 experts who completed the first round resulted in 32 different categories of visual perceptual disorders which, according to this panel, should be screened for after acquired brain injury or which could be associated with nonspecific visual complaints. Sixteen of these disorders were excluded from further elaboration, since these disorders are lower-level disorders or considered to be a regular part of an assessment for lower level visual function (see Table 4). Table 5 shows the results for the disorders that were, for the purpose of the present study, considered as mid-level or higher-order disorders. The table further shows the number of experts suggesting the particular disorder

Table 4. Visual perceptual disorders that were discarded after the first round.

Visual disorder	*N* (%)[a]
Visual field defects	14 (66.7)
Early processing deficits (e.g., visual acuity)	8 (38.1)
Impaired contrast sensitivity	8 (38.1)
Impaired light perception	6 (28.6)
Alexia/reading problems	5 (23.8)
Oculomotor disorders	4 (19.0)
Diplopia	4 (19.0)
Achromatopsia	3 (14.3)
Optic ataxia	2 (9.5)
Impaired depth perception	2 (9.5)
Accommodation deficits	2 (9.5)
Decreased awareness of visual deficits (monitoring)	2 (9.5)
Decreased night vision	1 (4.8)
Increased sensitivity to glare	1 (4.8)
Pseudohallucinations	1 (4.8)
Connectivity deficits	1 (4.8)

[a]Number (%) of experts who suggested the corresponding disorder.

Table 3. Arguments for test selection.

Subject	Description
1. Suggested by panel	The opinion of the expert panel was considered as framework. Therefore, test selection for every disorder started with the suggestions given during the second Delphi round. These results were evaluated in light of practical considerations (e.g., clinical utility) and the following three arguments.
2. Validation	Some tests suggested by the expert panel were still experimental in nature. Because of time constraints and because the test battery should be suitable for clinical practice, we proposed tests that were comparable to those suggested by the experts, that were validated and, if applicable, already digitally available.
3. Test-retest effects	The aim of this test battery is to discriminate between "impaired" and "not impaired" patients. Subsequent assessment of impaired patients will be more thorough than the screening in order to provide further insight into the disturbance. To avoid test–retest effects, we considered it as fair to spare more extensive and clinically widely distributed tests for use in its completeness in the more thorough subsequent assessment. In this case, we opted for a comparable test of shorter or the same time duration. An example would be a Complex Figure Test for the assessment of visual constructive skills. By selecting a clinically less distributed variant, the more widely used variant can still be used in its completeness in a more thorough and elaborated assessment.
4. Unique contribution	In some cases, test selection based on the suggestion of the panel resulted in the inclusion of subdomains of functioning that would be covered by tests already selected for the battery. In this case, a comparable test was selected, that would be less represented in the battery. This applies for example to mid-level functions, like perceptual organization. A factor analysis performed by Vancleef and colleagues (Vancleef et al., 2014) distinguished four perceptual factors: grouping, figure-ground, parts in whole, and shape discrimination. If the experts' opinion was representing a factor that would already be covered by other tests in the battery, a test was selected that was thought to measure a perceptual factor that was not yet included in the battery.

Table 5. Mid-level and higher-order visual perceptual disorders and tests resulting from round one.

			Test	
Visual perceptual disorder	Suggested by number of experts (%)[a]	Mean level of knowledge[b]	Selection of suitable tests as suggested by experts[c]	Suggested by number of experts (%)[d]
1. Non-lateralized attentional disorders/non-lateralized disorders in spatial cognition (e.g., visual search disorders, dorsal simultanagnosia)	13 (61.9)	2.9	1. VOSP[e]	7 (53.9)
			2a. Dot counting task	2 (15.4)
			2b. Complex Picture[f]	2 (15.4)
2. Lateralized attentional disorders/lateralized disorders in spatial cognition (e.g., neglect, extinction)	13 (61.9)	2.7	**1. Cancellation task**	11 (84.6)
			2. RBIT[g]	5 (38.5)
3. Visual agnosia not otherwise specified	12 (57.1)	2.9	1. VOSP[e]	4 (33.3)
			2. Object naming test	4 (33.3)
4. Temporal processing disorders/slow visual processing speed	8 (38.1)	2.3	1. Test including reaction time	5 (62.5)
			2. TMT[h]	1 (12.5)
5. Object agnosia	5 (23.8)	3.0	1. BORB[i]	2 (40.0)
6. Prosopagnosia	5 (23.8)	3.0	**1. BFRT**[j]	3 (60.0)
			2. Test including the recognition of famous and familiar faces	2 (40.0)
7. Reduced visual loading (in time and space)	5 (23.8)	2.6	1. Pattern Glare Test[k]	1 (20.0)
			2. Repeated visual field measurements	1 (20.0)
8. Disorders in perceptual organization	4 (19.0)	2.8	1. EFT[l]	2 (50.0)
			2. Overlapping figures test	1 (25.0)
9. Spatial (working) memory disorders	4 (19.0)	3.0	1. RCF[m]	2 (50.0)
			2. BJLO[n]	1 (25.0)
10. Disorders in movement perception	4 (19.0)	2.1	**1. Random Dot/motion coherence**	3 (75.0)
			2. Object from motion test	1 (25.0)
11. Visual form agnosia	3 (14.3)	2.7	1. VOSP[e]	1 (33.3)
			2. VOT[o]	1 (33.3)
12. Visual constructive disorders	2 (9.5)	3.5	**1. RCF**[m]	2 (100)
13. Brightness & color agnosia	1 (4.8)	4.0	1. Ishihara[p]	1 (100)
14. Disorders in emotion perception	1 (4.8)	4.0	1. Unspecified	1 (100)
15. Topographic agnosia	1 (4.8)	2.0	1. Drawing a map	1 (100)
			2. Verbal route description	1 (100)
16. Cross-modal integration	1 (4.8)	2.0	1. Cross-modal integration paradigms	1 (100)

[a]Number of experts who suggested the visual perceptual disorder ($n = 21$).
[b]Mean level of knowledge of the experts who suggested this disorder: 1 = basic, 2 = intermediate, 3 = advanced, 4 = expert.
[c]Selection of the two most often suggested tests. If multiple tests were mentioned once, either the test that was proposed in the second round or any other suggested test was chosen to be shown in the table. If there was no second most often suggested test, only one test is presented.
[d]Number of experts who suggested the test (of those experts who suggested to screen for the corresponding visual perceptual disorder).
[e]VOSP: Visual Object and Space Perception battery (Warrington & James, 1991).
[f]Complex Picture: Complex Picture Description Task.
[g]RBIT: Rivermead Behavioural Inattention Test (Wilson, Cockburn, & Halligan, 1987).
[h]TMT: Trail Making Test (Reitan, 1958).
[i]BORB: Birmingham Object Recognition Battery (Riddoch & Humphreys, 1993).
[j]BFRT: Benton Facial Recognition Test (Benton, Sivan, Hamsher, Varney, & Spreen, 1994).
[k]Pattern Glare Test (Wilkins & Evans, 2001).
[l]EFT: Embedded Figures Test.
[m]RCF: Rey Complex Figure (Rey, 1941).
[n]BJLO: Benton Judgement of Line Orientation (Benton, Varney, & Hamsher, 1978).
[o]VOT: Hooper Visual Organization Test (Hooper, 1958).
[p]Ishihara: Ishihara Color Plate Test (Ishihara, 1992).
Note. All tests that are printed in bold were proposed to the expert panel in the second round for inclusion in the test battery (see method section for the selection criteria).

as being of relevance, their mean level of knowledge about the disorder they suggested, a selection of the tests that are most often suggested by the experts as being most suited to assess the specific disorders and the number of experts suggesting the individual tests. All tests in Table 5 that are printed in bold were proposed to the expert panel in the second round as being suited for inclusion in the test battery.

Second round

Nineteen experts completed the second round. The results are shown in Table 6. The visual perceptual disorders in the table are organized based on the median position in the expert rankings. Furthermore, the percentages of experts indicating that a particular visual perceptual disorder should be included in the test battery and who were neutral about this are reported. For each disorder, the test that was, according to the experts' opinion, most suited to screen for this disorder is presented in the table. The test that was considered as the experts' opinion in the second round was based on one of three principles, that is, (1) the number of experts indicating agreement to the proposed test as being most suited to assess the particular disorder (only for tests that were mentioned in the first round by more than 50% of those experts that mentioned the corresponding disorder, see column "N (%) of agreement"); (2) the

Table 6. Mid-level and higher-order visual perceptual disorders and tests resulting from round two.

			Test					
Visual perceptual disorder	Median rank[a]	*N* of experts for inclusion in test battery (% agree/ neutral)[b]	Test considered as experts' opinion[c]	Evaluated by *N* experts[d]	*N* (%) of agreement[e]	Median rank[f]	Mentioned by *N* (%) experts[g]	Mean level of knowledge[h]
Lateralized attentional disorders/ lateralized disorders in spatial cognition (e.g., neglect, extinction)	1	18 (94.7/0)	Bells Test[i]	18	11 (61.1)			2.6
Non-lateralized attentional disorders/non-lateralized disorders in spatial cognition (e.g., visual search disorders, simultanagnosia)	3	19 (94.7/5.3)	Dot Counting	18	12 (66.7)			2.4
			Complex Picture[j]	17	8 (47.1)			2.3
Temporal processing disorders/slow visual processing speed	4	17 (78.9/10.5)	TMT[k]	17	10 (58.8)			2.4
Disorders in perceptual organization	6	18 (78.9/15.8)	EFT[l]	16		2		1.8
Object agnosia	6	17 (73.7/15.8)	BORB[m]	11	10 (90.9)			1.6
Reduced visual loading (in time and space)	7	17 (89.5/0)	Visual search/ crowding task	11			5 (45.5)	2.4
Spatial (working) memory disorders	8	18 (78.9/15.8)	RCF[n]	17		1		2.5
Visual constructive disorders	9	17 (73.7/15.8)	RCF[n]	17	15 (88.2)			2.5
Disorders in movement perception	10	15 (63.2/15.8)	Random Dot	13		1		2.2
Visual form agnosia	11	17 (73.7/15.8)	VOSP[o]	16		1		2.2
Prosopagnosia	11	13 (47.4/21.1)	BFRT[p]	12	9 (75.0)			1.9
Visual agnosia not otherwise specified	11	13 (36.8/31.6)	VOSP[o]	12		1		1.9
Brightness & color agnosia	13	14 (52.6/21.1)	Color sorting test	6			4 (66.7)	2.3
Topographic agnosia	14	14 (52.6/21.1)	Verbal description	12	6 (50)			1.7
Disorders in emotion perception	14	13 (36.8/31.6)	Pictures of faces with different emotions	2			2 (100)	2.0
Cross-modal integration	14	10 (42.1/10.5)	Combination of tests, such as writing and reading	1			1 (100)	3.0

[a]Median position of the visual perceptual disorder in the expert ranking.
[b]Number (%) of experts that agreed/were neutral about the visual perceptual disorder for inclusion in the test battery.
[c]Test that was proposed by most of the experts to assess the corresponding visual perceptual disorder.
[d]Number of experts who suggested/evaluated a test to screen for the corresponding disorder.
[e]Number (%) of experts that agreed with a proposed test on a 3-point Likert scale (agree-neutral-disagree).
[f]Median position of the test of experts' opinion in the expert ranking.
[g]Number (%) of experts that mentioned the test of experts' opinion on the open-ended questions.
[h]Mean level of knowledge of the experts who suggested this test: 1 = I have little knowledge about this test, 2 = I know this test well, 3 = I know this test very well.
[i]Bells Test (Gauthier et al., 1989).
[j]Complex Picture: Complex Picture Description Task.
[k]TMT: Trail Making Test (Reitan, 1958).
[l]EFT: Embedded Figures Test.
[m]BORB: Birmingham Object Recognition Battery (Riddoch & Humphreys, 1993).
[n]RCF: Rey Complex Figure (Rey, 1941).
[o]VOSP: Visual Object and Space Perception battery (Warrington & James, 1991).
[p]BFRT: Benton Facial Recognition Test (Benton et al., 1994).

median ranking of all tests suggested by the experts per disorder (only for disorders for which no test had been suggested by more than 50% of the experts in the first round, see column "Median rank"); and (3) the number of experts suggesting another test (only for those disorders for which no tests emerged during the first round that could be proposed to the panel, see column "Mentioned by N (%) experts"). Table 7 shows the composition of a test battery that resulted from the second round and that has been proposed to the expert panel in the final third round. The last column in Table 7 shows the argument on which the selection of a particular test has been based on (see Table 3 for an explanation of the different arguments).

Table 8 shows the responses of the expert panel with regard to the exclusion of the visual perceptual disorders that are considered to be regular part of a lower level visual function assessment. In 14 out of 16 visual perceptual disorders, there was no disagreement at all. Some disagreement was observed concerning pseudohallucinations and connectivity deficits. While 3 experts (i.e., 15.8% of the expert panel) disagreed to the exclusion of pseudohallucinations from further elaboration within this study, one expert (i.e., 5.26%) disagreed to exclude connectivity deficits. Consequently, consensus on exclusion of the visual disorders that are considered to be part of a lower-level visual assessment was reached.

Table 7. Composition of test battery resulting from round two.

	Visual perceptual disorder	Test	Argument[l]
1.	Lateralized attentional disorders/lateralized disorders in spatial cognition (e.g., neglect, extinction)	Bells test[a]	Suggested by panel
2.	Visual search disorder[h]	Dot Counting Task	Suggested by panel
3.	Simultan agnosia[h]	Complex Picture[b]	Suggested by panel
4.	Temporal processing disorders/slow visual processing speed	TMT[c]	Suggested by panel
5.	Disorders in perceptual organization	Figure Ground Segmentation[d]	Unique contribution
6.	Object agnosia	Silhouettes[e]	Validation
7.	Reduced visual loading (in time and space)	Crowding Task	Suggested by panel
8.	Spatial (working) memory disorders	CBTT[f]	Test-retest effects
9.	Visual constructive disorders	TCF[g]	Test-retest effects
10.	Disorders in movement perception	Global Motion Detection[d]	Validation
11.	Visual form agnosia	Shape Ratio Discrimination[d]	Validation

[a]Bells Test (Gauthier et al., 1989).
[b]Complex Picture: Complex Picture Description Task.
[c]TMT: Trail Making Test (Reitan, 1958).
[d]L-Post (Torfs et al., 2013. Vancleef et al., 2014).
[e]Silhouettes: Visual Object and Space Perception Battery (Warrington & James, 1991).
[f]CBTT: Corsi Block-Tapping Task (Corsi, 1972. Kessels et al., 2000).
[g]TCF: Taylor Complex Figure (Taylor, 1969).
[h]Nonlateralized attentional disorders/non-lateralized disorders in spatial cognition.
[l]For further explanation please view Table 3.

Third round

A total of 17 experts participated in the third round, of which 16 experts (94%) indicated to agree with the proposed test battery. The one expert who did not agree argued that the Bells Test (Gauthier, Dehaut, & Joanette, 1989) requires intact object recognition and that therefore the Balloons Test (Edgeworth, Robertson, & McMillan, 1998) would be a purer measure for lateralized attentional disorders. Despite our agreement with the rationale of this expert, the aim of a screening tool is to indicate possible deficits that should guide further assessment, not to detect specific disorders. Prior to contacting experts, consensus was defined to be reached if 80% of the expert panel agreed to a test battery. With the achieved agreement of 94% of the experts, no further rounds were necessary.

Table 8. Results on excluded visual disorders.

Visual disorder	Disagreement *N* (%)[a]
Visual field defects	0
Early processing deficits (e.g., visual acuity)	0
Impaired contrast sensitivity	0
Impaired light perception	0
Alexia/reading problems	0
Oculomotor disorders	0
Diplopia	0
Achromatopia	0
Optic ataxia	0
Impaired depth perception	0
Accommodation defects	0
Awareness of visual deficits (monitoring)	0
Decreased night vision	0
Increased sensitivity to glare	0
Pseudohallucinations	3 (15.8)
Connectivity deficits	1 (5.26)

[a]Number (%) of experts that disagreed with the exclusion of the visual disorder.

Discussion

The goal of this study was to apply the Delphi method in order to get agreement on a test battery which can be used for the screening of visual perceptual disorders in patients with ABI. After the final third round, 94% of the experts agreed with the proposed test battery, consisting of eleven short visual perceptual tests, each assessing a distinct visual perceptual domain. The test battery is composed of specific tests that have previously been published (i.e., Bells Test; Gauthier et al., 1989), TMT (Reitan, 1958), L-Post (Torfs et al., 2013; Vancleef et al., 2014), Silhouettes (Warrington & James, 1991), Corsi Block-Tapping Task (Corsi, 1972; Kessels, van Zandvoort, Postma, Kappelle, & de Haan, 2000), and Taylor Complex Figure (Taylor, 1969)), and tests that are available as (sub)tests in several existing test batteries (i.e., Dot Counting; e.g., VOSP; Warrington & James, 1991) and Complex Picture Description Task (e.g., Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1983)). The inclusion of tests that are already available makes it easy for clinicians but also researchers to apply the test battery. As the battery was composed based on the opinions and agreement of an international panel of experts in the field, the battery will surely contribute in improving the standards and the quality of patient care. However, there are also tests suggested by the panel that are not freely or commercially available yet and therefore need to be specifically developed for this battery (e.g., Crowding Task). Two of these tests (i.e., Global Motion Detection and Crowding Task) can only be administered digitally, while the other tests could be administered both digitally and using a paper and pencil version. The presented test battery will,

in its completeness, have an expected administration time of about 30 minutes.

To the best of our knowledge, the current study is the first in using a Delphi method for the development of a test battery for the screening of mid-level and higher-order visual perceptual functions. Previously, a study applying the Delphi method in a related field has been carried out in order to develop a screening protocol for lower-level perceptual deficits following mild traumatic brain injury (Goodrich et al., 2013). This protocol provided guidelines for ocular problems, like accommodation deficits or diplopia. A theory-based neuropsychological screening instrument for mid-level processes of visual perception has been composed by Torfs and colleagues (Torfs et al., 2013). This online instrument includes 15 subtests that measure deficits in mid-level processes such as figure-ground segregation and shape perception. According to Torfs et al. (2013), a neuropsychological screening instrument for visual disorders should include tests that do not rely on high level processes like object recognition, but should screen for processes on which higher-order disorders are dependent. However, the present tool includes tests for the screening of both mid-level and higher-order visual perceptual disorders as the aim of a screening instrument is usually not to detect specific disorders, but to indicate possible abnormalities of a wide range of functions. This should initiate and guide further assessment to explore the nature of these abnormalities, including mid-level visual functions as proposed by Torfs et al. (2013).

The proposed test battery encompasses several strengths. First, the test battery is composed based on the opinions of a panel of multidisciplinary experts in the field of visual perception, combining a broad range of perspectives on and extensive experience in visual disorders and their assessment (Murphy, 1998). Since experts could indicate to not feel qualified for a particular question, there is no reason to assume that the different perspectives have led in any way to questionable results. Second, a broad range of visual perceptual functions can be screened for in only 30 minutes of administration time. That is, not only tests for visual perceptual disorders that are considered most common after ABI are included in the battery. Also, tests for visual functions that, according to the expert panel, do currently get insufficient attention in clinical practice and should be more adequately assessed are included, as well as tests for visual functions that could be associated with nonspecific visual complaints. There is a chance that visual disorders that are considered to be rare (e.g., cerebral akinetopsia, Ardila, 2016; Zihl, von Cramon, & Mai, 1983) are actually more common in real clinical practice than assumed, possibly because these disorders are insufficiently screened for or not recognized by the clinician based on the nonspecific terms in which patients describe their complaints, which points toward the third strength: The current test battery is not theory-driven or based on one specific model, but combines both scientific and clinical perspectives, making it suitable for both research and clinical purposes. Finally, as some tests suggested by the expert panel have to be administered digitally, a battery like suggested in this study could be programmed for tablet PCs, allowing for the advantages of computerized testing over conventional paper and pencil tests, including objective scoring of test results by automatic data processing, more accurate measurement of reaction times, time effectiveness (e.g., time spent on preparation and scoring), cost effectiveness, and most importantly, the presentation of dynamical stimuli (i.e., motion perception) (Bauer et al., 2012; Kurzbuch et al., 2013; Torfs et al., 2013). An additional strength of digital versions of these tests would be that tests could directly be linked to normative data (e.g., according to age, gender, and/or education), which could further result in a clinical report adjusted to the needs and wishes of the clinical practitioner.

Despite the strengths of the suggested test battery, some limitations concerning this study need to be considered. The first limitation concerns the number of dropouts. In total, we encountered a drop-out rate of 39% of the initial sample. Based on the sample characteristics (number of publications, years of experience in visual perception), there are no indications to assume that these dropouts have lowered the expert qualification level of the panel. Moreover, consistency is given as out of the 17 experts who participated in the third round, 16 participated in all three rounds. Since high dropout rates are common in studies using a Delphi method, especially in the final rounds (H. P. McKenna, 1994), the number of dropouts in our study can be considered to be within an acceptable range. Nevertheless, a larger sample consisting of experts from more diverse demographic regions would have been desirable. This is relevant as a considerable proportion of the present expert panel come from The Netherlands or Germany, and may thus not represent demographic regions outside Europe adequately. A larger panel, consisting of more experts from countries outside Europe, might have proposed different measures, leading to a different consensus on a test battery for the screening of visual perceptual disorders. However, the tests proposed by the reviewers during the rounds of the Delphi as well as the tests forming the final battery are primarily tests that are internationally available, recognized and frequently applied in the clinical and scientific contexts.

Therefore, the chance that different tests would have been suggested by more experts outside Europe should not be overestimated. Second, some tests and ideas proposed by the expert panel were still experimental in nature. Despite the potential value of these tests and ideas, including them in the consensus process was impossible because of time constraints and the aim to compose a test battery that can easily be implemented into clinical practice. Additionally, this would have required more Delphi rounds, risking an increase in dropouts, in particular as the number of dropouts is assumed to raise drastically with an increase in the number of rounds (Whitman, 1990). Furthermore, it cannot be assumed that all experts are informed or experienced with these experimental paradigms, as the paradigms have been applied in experiments with very specific research questions and under strict experimental control. Therefore, consensus would be difficult to reach. Nevertheless, this study might have been more comprehensive if these experimental tests and ideas would have been considered as well. Third, it is (more or less) inherent to studies using Delphi methods that the questions addressed in each round and the interpretation of responses may be subject to bias of the researchers. To limit the effects of such bias the expert panel was provided with a transparent summary of all results of the previous round and the expert panel was given the possibility to comment on each step in the process at all times. Even though this does not fully exclude the possibility that bias may have influenced the process or the eventual outcome of the Delphi, the involvement of the researchers in the Delphi process was aimed to guide and facilitate the process in order to limit the number of rounds, nonetheless leaving the final decision regarding the test battery to the expert panel. During the study none of the participants commented on the process itself or the questions addressed in a particular round. Lastly, even though a Delphi method has high face validity (Boulkedid et al., 2011), the proposed test battery needs to be examined on its' psychometric properties, including its reliability and validity, as only this would reveal the battery's clinical and scientific utility. Moreover, normative data of different populations (e.g., healthy individuals and individuals with brain injury) need to be collected.

In conclusion, the current article reported on a study using a Delphi method focusing on the composition of a neuropsychological test battery aiming at the comprehensive screening of a broad range of mid-level and higher-order visual perceptual disorders. Consensus is achieved on a test battery consisting of 11 distinct visual perceptual tests with little administration time of about 30 minutes in total. The results of such screening assessment may be useful to guide clinical assessment by providing insight into patients' deficit, thereby supporting the planning and elaboration of further assessment. Effectiveness of clinical assessments of visual perceptual disorders may therefore be improved. Scientifically, the proposed battery could facilitate comparison across studies investigating visual perceptual disorders following acquired brain injury. Future studies should focus on application and validation of this battery. Furthermore, normative data of different populations need to be collected for this test battery and made available.

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