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Neuropsychological assessment and telemedicine: A preliminary study examining the reliability of neuropsychology services performed via telecommunication

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Abstract

Within the last decade, various applications of two-way audio-visual telecommunication have been implemented in the Norwegian health care system to facilitate the delivery of medical services to patients located in rural areas away from the hospitals. This technology may also be useful to extend neuropsychological services to underserved areas and thereby reduce the patients' travel time and costs. In the current study, a total of 12 visual, verbal and performance tests were administered face-to-face and via videophones to 32 volunteer participants to examine the consistency and stability of test-scores when delivered via different formats. The obtained reliability coefficients ranged from .37 to .86 with a median value of .74. When testing for mean differences, the measures on verbal learning (WMS–Logical Memory I) and auditory attention (Seashore Rhythm Test) differed significantly due to administration format ($t = 2.34$, $p = .024$ and $t = 2.37$, $p = .025$, respectively). The findings imply that administration format does not appear to affect the reliability of measurement but neuropsychological test performance is significantly higher for the measures of attention and memory when delivered via videophone. Additional research on these cognitive domains is required, and if the observed differences due to testing format persist, separate normative data via telecommunication will be required before assessments are carried out. Also, since only normal participants were included in this study, the findings may have external validity for normal populations, but similar controlled trials with patients need to be completed before remote assessments can be implemented in regular clinical practice. (*JINS*, 2003, *9*, 472–478.)

Keywords: Neuropsychological assessment, Telemedicine, Telecommunication

INTRODUCTION

Telemedicine refers to various applications of telecommunication technology used to extend medical services to patients located in geographical areas away from the physician. The initial use of telecommunication to deliver health services dates back to the invention of the telephone. Remote consultations were introduced in Norway during the 1920s, when the Haukeland hospital in Bergen established a telephone link between the maritime fleet and physicians for sailors to consult for diagnosis and treatment (Rafto, 1955). In the mental health field, videophones were used for two-way audio-visual communication in Nebraska in the United States as early as 1961. By 1970, over 1200 hr of group therapy and consultation via videophones were logged, but the Nebraska programs were discontinued due to the immense costs of equipment as well as high broadcasting expenses (Wittson & Benschoter, 1972). With the increased availability of digital two-way sound and picture technology, mental health programs via telecommunication have re-emerged during the last decade in Australia (Hawker et al., 1998), Canada (Doze et al., 1999), Norway (Gammon et al.,

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1996), Scotland (Kirkwood et al., 2000) and the United States (Brown, 1995). According to a recent survey, there are 15 Norwegian institutions that use telecommunication technology for clinical psychology (Uldal, 1999).

Opinions About Telemedicine

A review of the current clinical literature indicates that experiences with using various applications of telemedicine for somatic consultations are overwhelmingly positive (Allen & Hayes, 1995; Loane et al., 1998; Mekhjian et al., 1999; Pedersen & Holland, 1995), while experiences with conducting remote mental health services yield varying results. Of particular interest are findings that indicate that psychologists tend to be more apprehensive about this technology than are their patients in treatment. Data as far back as 1974 indicate that clinicians were reluctant to offer telepsychiatric consultations because the distance was thought to negatively affect the therapeutic alliance although telepsychiatry in the end turned out to be more successful than any other application of this technology (Murphy & Bird, 1974). Recent surveys on patient satisfaction indicate that patients respond favorably to this type of intervention while clinicians still express a preference for face-to-face interaction (Doze et al., 1999; Stevens et al., 1999). However, as clinicians become more familiar with communicating via a telecommunications link, the acceptance rate appears to increase. Gammon et al. (1996) found that the majority of 951 mental health professionals were either satisfied or highly satisfied with using telemedicine in their clinical work, and only 2% reported being highly dissatisfied.

Psychological Assessment

Although there has been a recent increase in remote clinical psychology, a review of the current literature yields relatively few controlled studies describing assessment methods via telecommunication. Montani et al. (1997) examined the reliability of remote psychometric consultations by comparing the performance on the Mini-Mental Status Examination and the Clock Face Test via videophones with conventional, face-to-face testing. They uncovered small, but significant decrements among 10 elderly individuals (average age 87) on these measures. They also explained that communication becomes more difficult via a videophone and that variables such as manipulation of equipment are likely to distract both the clinician and the patient. In a similar study, Freir et al. (1999) reported correlations ranging from .30 on story recall tests to .98 on tests of reading ability when comparing the two media.

The Sunnaas Rehabilitation hospital initiated a research program in 1994 to evaluate neuropsychological assessment via videophones. This hospital admits patients from all regions of Norway and in this setting, remote-testing would be useful (1) to determine if a patient should be referred to specialist rehabilitation and (2) for repeated testing after hospital discharge to measure any change in neuropsychological status. Performing remote screenings requires that neuropsychological performance via telecommunication is consistent with face-to-face assessment and that a sufficient number of measures is available for this purpose. As a first step, all the tests that are in use at our clinic were attempted via videophones with a document camera between two psychologists. A total of 25 measures were found to be possible to administer via telecommunication without requiring a testing assistant present at the remote location to administer the testing material. These 25 tests were then classified according to the cognitive functions they assess and a total of 12 of these measures were selected for our study based on the following criteria: (1) One measure corresponding to each area of functioning normally included in a standard neuropsychological assessment was selected; (2) to the extent possible, tests with separate parallel forms or measures with a sufficient number of independent items for split-half half evaluation were included to minimize test–retest effects; (3) tests of short duration were chosen in order to enable us to include as many different measures as possible within a 1-hr test session; and (4) a variety of visual, verbal, and motor tests were selected to examine the limitations of testing via telecommunication.

METHODS

Research Participants

Thirty-two normal volunteers, 13 males and 19 females, participated in the project. The average age of the subjects was 34.8 (*SD* = 10.3, range 18–57 years) with a mean educational level of 16.6 years (*SD* = 2.6, range 11–21). The average age of the subjects tested initially via telecommunication was 36 years compared to 34.1 years for the half tested in the opposite order and the mean educational level differed by less than one year between the two groups. The subjects were recruited among the staff at the Sunnaas Rehabilitation Hospital and the participants were compensated for completing the assessments. Subjects with a known history of neurological or psychiatric illness were excluded from the study. The study also excluded individuals with any prior experience with neuropsychological testing.

Equipment

Two videophones, a Tandberg 5000 located at the psychologist's studio and a Polyspan View Station at the subject's location were used for this study. Picture and sound were transmitted via three parallel ISDN units[1] (384 kbit/s). This quality was determined to be the minimum quality for a

[1]ISDN refers to Integrated System Digital Network, a relatively high bandwidth connection in which voice, data, and still and moving pictures are transmitted in digital form at high speed. ISDN lines have multiple channels capable of transmitting information simultaneously with bandwidth up to 128 kbit/s (Jones & Colenda, 1997)

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synchronized sound/picture. Also, with neuropsychological testing where frequent movements by the clinician are required to demonstrate various tests, a 384 kbit/s transmission was required for a sufficient resolution (clarity of picture). The video images transmitted to the subject were either live pictures of the psychologist or visual test material presented via a document camera (JVC visual presenter AV-P700); the document camera was included to enhance the resolution of the visual and printed material. The cameras in both studios had free directional movement and zooming functions and the camera in the subject's studio was remote controlled by the psychologist. Two-way sound was maintained throughout the test session. Prior to the initial testing session, the subjects received information about the purpose of the experiment as well as the testing procedures and prior to the telecommunication session, the telemedicine equipment was demonstrated by the psychologist.

Procedure

The participants were administered an abridged neuropsychological battery consisting of standardized tests. The cognitive domains included, the measures used to examine these functions and the testing procedures are outlined in Table 1. The subjects were tested over two sessions within the same day, one session face-to-face and another via videophones. Each test session lasted approximately 50 min. A cross-over design was chosen to alleviate the possibility of differential learning effects. The participants were randomly assigned to one of two experimental groups; one half of the subjects were initially tested face to face, followed by a test session via telecommunication. The other half was tested in the opposite order. Three of the participants completed the remote session a few days after the initial testing due to technical difficulties. The assessments were performed by two licensed psychologists, but each subject was tested by the same investigator during both testing conditions. The subjects were alone in the studio throughout the test session via telecommunication. The tests were administered according to instructions contained in their respective manuals. During the remote session, the Grooved Pegboard and the Symbol Digit Modalities Test (SDMT) were demonstrated via the document-camera to assure that the subject used the correct object or recording sheet. For the Visual Object and Space Perception (VOSP) battery and the Benton Visual Retention Test (BVRT), all the items were transmitted via the document camera during the remote session. The testing equipment necessary to complete the telecommunication trial were located in the testing studio on a desk in front of the subject and included a Grooved Pegboard, a record sheet for the SDMT, a recording booklet for the BVRT and several pencils.

Upon completion of the testing, the participants were interviewed about their opinions regarding communication, perceived distance, presentation of the instructions and preferred testing condition.

Statistical Analysis

The performance on each measure was recorded for all participants and the raw score distribution for the two groups was converted into T scores based on the normative data presented in the following publications: Pegboard and Seashore (Heaton et al., 1991), Visual Object and Space Perception (VOSP; Warrington & James, 1991), Benton Visual Retention Test (BVRT; Youngjohn et al., 1993), Symbol Digit Modalities Test (Lezak, 1995), Digit Span and Vocabulary (WAIS, Norwegian Version; Engvik et al., 1978) and Logical Memory I and II (WMS–R; Wechsler, 1987).

Reliability coefficients were computed for each test to examine the consistency and stability of test-scores when delivered via different formats. The obtained coefficients in the present study were then compared to reliability information published in the test manuals or in other relevant publications. For seven of the tests, a split-half procedure was used to estimate internal consistency. The split-half procedure for the VOSP, the BVRT, and the vocabulary subtest of the WAIS involved correlating scores on the even

Table 1. Cognitive domains and related neuropsychological measures: Presentation method and response mode via telecommunication

Cognitive domain	Test	Presentation	Response
Visuomotor speed	Grooved pegboard (Kløve, 1963)	Document camera	Performance
Auditory attention	Seashore Rhythm Test (Seashore et al., 1960)	Auditory	Verbal
Verbal memory	Logical Memory subtest from the Wechsler Memory Scale–Revised (WMS–R; Wechsler, 1987)	Verbal	Verbal
Nonverbal memory	Benton Visual Retention Test (BVRT; Benton, 1974)	Document camera	Written
Visual perception	The Silhouette subtest from the Visual Object and Space Perception Battery (VOSP; Warrington and James, 1991)	Document camera	Verbal
Verbal ability	The vocabulary subtest from the Wechsler Adult Intelligence Scale (WAIS; Norwegian version; Engvik et al., 1978)	Verbal	Verbal
Attention	Digit span subtests from the WAIS/WMS–R	Verbal	Verbal
Information processing	Symbol Digit Motor Test; SDMT (Smith, 1982)	Document camera	Written/Verbal

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and odd numbered items. The half tests used for the Logical Memory I and II consisted of Story A and B, the variables used for the BVRT included the C and D forms and for the Digit Span subtest, the WMS–R and the WAIS versions were correlated. The reliability coefficients presented for the Wechsler tests have been corrected by the Spearman-Brown formula for the full subtest (Crocker & Algina, 1986). With the exception of the Digit Span subtest, the procedure used for estimating reliability coefficients is in accordance with the formula presented in the Wechsler manuals (WMS–R; Wechsler, 1987; WAIS, Norwegian version; Engvik et al., 1978). For the remaining tests, stability coefficients were obtained by administering the same test twice. Paired *t* tests were used to analyze mean differences and independent *t* tests to assess interaction effects between test–retest effects and administration format. The significance level was set at .05.

RESULTS

For most of the measures sampled, the neuropsychological test scores via different formats were highly correlated. The average reliability coefficients of the tests ranged from .37 to .86 with a median value of .74. When testing for mean differences, the measures on verbal learning (WMS–Logical Memory I) and auditory attention (Seashore Rhythm Test) differed significantly due to administration format ($t = 2.34$, $p = .024$ and $t = 2.37$, $p = .025$, respectively). For five of the neuropsychological variables, the results differed by less than 1 T-score point with a maximum difference of 3.16 T-score points (WMS–Logical Memory 1) and for eight of the measures, the mean test performance was slightly higher via telecommunication. When testing for interaction effects between administration format and presentation sequence with independent samples *t* tests, significant effects were found for both the Logical Memory I ($t = 2.47$, $p = .020$) and the Seashore Rhythm test ($t = 2.36$, $t = .26$). Neuropsychological scores, reliability coefficients and *t* values are presented in Table 2.

DISCUSSION

For most of the neuropsychological tests, the performance via telecommunication was highly consistent with conventional testing and the reliability coefficients obtained in the current study were, for most measures, comparable to other findings. The internal consistency estimates for the Logical Memory I and II obtained in our study were slightly higher than the average values for the standardization sample reported in the WMS–R test manual ($r = .82$ *vs.* .74 for the Logical Memory I test and .79 *vs.* .75 for the Logical Memory II measure) while the internal consistency obtained for the Vocabulary subtest was slightly lower than the value reported in the Norwegian WAIS manual ($r = .86$ *vs.* .90). For the Digit Span subtest the average reliability coefficient in our study is significantly higher ($r = .82$ *vs.* .64) but this finding should be interpreted with caution since we used a different computational procedure. The stability (test–retest) coefficients obtained for the Seashore Rhythm Test, the Grooved Pegboard and the BVRT are also comparable to other findings. Bornstein et al. (1987) reported reliabilities on the Seashore test ranging from $r = .50$ to .77, Kelland et al. (1992) reported $r = .82$ for the Grooved Pegboard, and Youngjohn and his coworkers reported test–retest coefficients of .57 for number correct and .53 for errors on the BVRT. In our study, the oral portion of the SDMT was the measure with the lowest reliability ($r = .37$) a value which compares unfavorably with $r = .76$, reported by Smith (1982). The reason for the low stability on this test may have resulted from an insufficient lapse between test and

Table 2. Neuropsychological test scores via telecommunication and face-to-face assessment

	Telecommunication				Conventional administration							
Neuropsychological test	Mean score	(*SD*)	Mean T score	(*SD*)	Mean score	(*SD*)	Mean T score	(*SD*)	*r*	*t*	*df*	*p*
Pegboard dominant	59.2	(7.7)	51.2	(8.6)	58	(9.2)	54.3	(12.6)	.83	1.35	30	.19
Pegboard nondominant	65.1	(8.2)	51.0	(9.5)	63.9	(9.8)	52.7	(9.8)	.71	.941	30	.35
VOSP Silhouettes[a]	11.8	(2.2)	51.3	(10.9)	11.8	(2.0)	51.0	(9.8)	.64	.20	31	.84
Benton–correct response	7.8	(1.4)	50.0	(10.5)	7.6	(1.3)	48.1	(9.8)	.64	1.13	29	.27
Benton–error responses	3.0	(2.2)	50.7	(10.0)	3.1	(2.1)	49.8	(9.4)	.62	−.49	29	.63
SDMT oral	63.5	(11.9)	51.7	(10.3)	64	(11.9)	52.0	(12.9)	.37	−.21	30	.83
SDMT written	63.4	(14.9)	59.0	(15.8)	62.7	(18.5)	58.2	(19.0)	.69	.29	30	.77
Seashore Rhythm Test	27.6	(2.1)	55.4	(5.9)	26.8	(2.8)	54.1	(7.6)	.77	2.37	29	.03
WAIS/WMS Digit Span	12.1	(2.2)	55.8	(10.0)	11.8	(1.8)	54.4	(8.9)	.82[b]	1.0	30	.33
WAIS Vocabulary[a]	29.5	(4)	58.8	(8.4)	29.6	(4.5)	58.9	(9.7)	.86[b]	−.22	31	.83
WMS–Logical Memory I[a]	16.3	(3.6)	58.9	(9.7)	15.1	(3.75)	55.7	(9.8)	.82[b]	2.34	31	.02
WMS–Logical Memory II[a]	14.6	(8.8)	58.6	(10.3)	13.6	(3.8)	55.9	(9.4)	.79[b]	1.40	30	.17

[a]Raw scores and standard deviations for each half test.
[b]The reliability coefficients presented have been corrected by the Spearman-Brown formula for the full subtest (Crocker & Algina, 1986).

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retest rather than a true effect of testing format. The average test–retest improvement on this measure was exactly 1 standard deviation (T scores 47–57) and a visual inspection of the raw scores reveals a differential learning rate among the subjects. According to Smith (1982) only small practice effects in both the written and oral versions can be expected with a retest lapse of 1 month (Smith, 1982) and we therefore recommend an increase in retest time for future research. No internal consistency data have been found for the VOSP.

When testing for mean differences, significant discrepancies were found only for the measures of verbal learning and auditory attention. Kirkwood et al. (2000) found similar inconsistencies on story recall tests, although their results indicated an overall lower performance during the teletesting condition. These authors suggested that this difference may have been caused by reduced sound quality (1 ISDN unit; 128 kbit/s) and recommended a wider bandwidth for future research to overcome these technical limitations. In our study, a wider bandwidth was used and the participants reported no communication difficulties, nor any difficulties with understanding the test instructions when delivered via videophones. The reason for the difference in performance on the verbal learning and auditory attention variables in our study remains unclear, but a plausible explanation was uncovered during the exit interviews. Several participants explained that they felt less distracted during testing via telecommunication due to the perceived distance from the investigator, a factor which made it easier to focus on the task. Previous research has also suggested that some patients are more comfortable with remote testing than with an examiner present at the same location (Elford et al., 2000).

As for the interaction effects (Logical Memory I and Seashore), the performance on the second presentation via telecommunication exceeded all other conditions, most likely due to a combination of the treatment and carry-over effects described above. From a clinical standpoint, differences of as little as 3 T-score points are not likely to influence neuropsychological test interpretation. However, a comparison of the performance by the sample tested initially via videophones with the subjects tested in the opposite order yields some interesting findings. For the Logical Memory I variable, the performance of subjects tested initially via telecommunication was nearly identical for the first and the second test session. For the sample tested in the opposite order, however, the improvement from the initial face-to-face session to the following telecommunication trial exceeded 6 T-score points. This discrepancy is approaching a magnitude that could lead clinicians to erroneously conclude that the retest improvement reflects a true change in neuropsychological status, for example during repeated assessment via telecommunication after hospital discharge. Additional research on the Wechsler Memory Scale as well as other memory tasks will be required before drawing any firm conclusions and if these discrepancies due to testing format persist, normative data via a tele-link will be required before remote memory assessments can be carried out. The implication of the interaction effect is the same for the Seashore Rhythm test but the effect is less pronounced. The test-retest improvement for the group initially tested face to face was 2 T-score points while for the half of the sample tested initially by videophone, the score was identical for both sessions.

As previously explained, a combination of visual, verbal and performance tests were selected to examine the limitations of testing via telecommunication. Visual tests are possible to administer via telecommunication provided that the quality of sound and picture is sufficient to both deliver instructions and demonstrate the tests. Visual stimulus material with large figures may be reliably administered via a tele-link; the differences in performance between the two conditions for the visual tests included in this study, the VOSP and the BVRT, were some of the lowest of the entire battery. Tele-administration of visual tests with stimulus material focusing on small details, however, is questionable; an enlarged picture on a computer screen may change the impression of the pictures and therefore result in responses deviating from the normative data. Performance measures such as the Pegboard and pencil-and-paper tests require that the test equipment and record forms be present at the patient's location and a remote control camera is recommended for exact time measurement. If examination of tactile functions is required, a testing assistant will be required, at the patient's studio. With a testing assistant present at the satellite facility, a number of performance tests requiring active intervention may also be included, and the testing may be completed with reduced sound and/or picture quality.

The primary limitation of the current study is that only normal participants were included. Our results may have external validity for normal populations, but clinical samples with a neurological disorder may respond differently to this type of assessment. Similar controlled, randomized studies with various clinical samples may therefore be needed to extend these findings to patient populations. Further, individuals familiar with advanced technology may respond differently than others, and the differences in performance for various age groups may be considerable. As previously noted, significant decrements in performance among elderly on cognitive measures were detected by Montani et al. (1996). Age did not significantly affect the results in our study, but the mean age of our sample was only 34.8 years and the highest age was 57.

So far, this discussion has primarily focused on the psychometric aspects of remote assessment but, when evaluating the clinical utility of this technology, practical consequences also need to be addressed: How does the patient experience being tested by videophones? How does the clinician experience communicating with patients via a tele-link? And what are the implications for the health care system?

Satisfaction specifically with neuropsychological teleassessment has not been extensively described, but some

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limited evidence is encouraging. Montani et al. (1996) reported that remote consultations met patient acceptance although face-to-face testing was preferred and Kirkwood et al. (2000) reported that the majority of their patients would accept further treatment via telecommunication despite some dissatisfaction with the sound and picture quality. Our sample responded favorably to remote testing; the majority expressed no preference when asked to compare the two conditions. Only one participant expressed a strong preference for conventional test administration and explained that she experienced the distance as impersonal. Two participants ranked remote assessment higher and described that they felt less self-conscious about their performance with the examiner at a different location.

From the clinician's perspective, neuropsychological tele-testing is relatively demanding. There is an increased reliance on verbal communication and continuous eye contact needs to be maintained to assure the patient's attention. To maintain eye contact, the examiner is required to look directly at the camera located either on top or on the side of the monitor which precludes reading the test instructions from a manual. At the same time, the instructions need to be highly accurate to avoid unnecessary repetitions. The test material also needs to be well organized and within reach. Unnecessary movement, and particularly movement away from the patient's view to look for test material, is distracting for the patient. The communication between the subject and the psychologist will depend on both the quality of the technical equipment and the psychologist's familiarity with using this type of technology.

From the perspective of the health care provider, telemedicine has the potential of delivering specialist competence wherever this competence is required and thereby increase specialist productivity by reducing the travel time associated with outreach services. Norway has a total of 76 licensed clinical neuropsychologists (Norwegian Psychological Association) serving a population of approximately 4.3 million and these clinicians primarily practice at neuroscience clinics located in the urban areas. However, although telemedicine in general has proved to be a useful method to extend expertise to underserved areas, the technology needs to be used effectively to achieve this goal. The cost/benefit calculation needs to take into account the operating expenses, recurring expenditures for maintenance service, depreciation of equipment as well as upgrade expenses in addition to the initial costs incurred when acquiring the equipment. For neuropsychological testing via telecommunication, the cost calculation also needs to include expenses connected with sending test equipment to the patient's testing location or the costs involved with providing a satellite facility with test equipment. And finally, since Norwegian health care is to a large extent publicly funded, the cost/benefit analysis also needs to take into account the cost of reimbursing the patient's expenses when travelling to neuroscience clinics.

The findings presented in this article are encouraging, but additional evaluative studies will be required before remote neuropsychological assessment can be implemented in regular clinical practice. This article has emphasized psychometric aspects of remote neuropsychology, but we also suggest that future research in this area address how clinical observations are impacted by this type of technology. As noted above, similar controlled, randomized studies with various clinical samples may be needed to extend these findings to patient populations. And finally, only a limited number of neuropsychological measures were included in the present study, so the findings presented in this paper do not necessarily extend to other cognitive test variables.

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