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Relations between executive function, language, and functional communication in severe aphasia

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ABSTRACT

Background: Intervention in severe aphasia often means aiming for access to meaningful social interaction in spite of linguistic barriers that might not be treatable. This demands knowledge about the different factors that influence functional communication. Apart from linguistic ability, executive functions are thought to play an important role.

Aims: To expand the understanding of the relations of executive functions and linguistic ability to functional communication in severe aphasia.

Methods and Procedures: Executive functions, linguistic ability, and functional communication were assessed in 47 participants with severe aphasia. The results were analysed for the total sample and for a verbal and a nonverbal subgroup.

Outcomes and Results: Impairment of executive function was found in 85\% of the participants. There were moderate to strong correlations between all subtests of executive functions and linguistic ability. In the total sample, significant partial correlation was found between functional communication and verbal output. In the nonverbal subgroup, there was a significant partial correlation between executive function and functional communication, when controlling for linguistic ability. In the verbal subgroup, no relations were found between executive functions or language and functional communication.

Conclusions: Impairments of executive functions are common in people with severe aphasia, and executive function and linguistic ability are closely related. The ability to produce verbal output is strongly related to functional communication, but in people with extreme limitation or total absence of verbal output, executive functions seem to be an important factor for functional communication. There is a large variation of executive functions and functional communication in people with severe aphasia, especially in the nonverbal subgroup. It is important that people with severe aphasia are given a complete and proper evaluation of their abilities, and that the possible importance of executive function to communication is considered in communication intervention.
Introduction

Initial severity of aphasia is highly predictive of its persistence (Blom-Smink et al., 2017; Hanane El Hachioui et al., 2013; Glize et al., 2017). Individuals with severe aphasia are likely to live with the impairment in the long term, which warrants special interest in the communication and rehabilitation of this group. Aphasia has a profound effect on the well-being, social interactions and general quality of life of both the person with aphasia (PWA) and family members (Blom Johansson, Carlsson, Östberg, & Sonnander, 2012; Lam & Wodchis, 2010; Mazaux et al., 2013). People with severe aphasia (PWSA) have severe activity limitations regarding communication (Darrigrand et al., 2011), and the lack of communicative activity has a negative impact on mood and quality of life (Koleck et al., 2017). The ultimate goal of aphasia rehabilitation is the improvement of communication and social participation (van de Sandt-Koenderman, van der Meulen, & Ribbers, 2012). In severe aphasia, it is important to aim for access to meaningful social interaction in spite of the linguistic barriers that might not be treatable (Darrigrand et al., 2011; Koleck et al., 2017). To do this, we need a profound understanding of the components that, in addition to the linguistic ability, have an impact on communication in severe aphasia.

Communication is a highly unpredictable activity, which demands on-line monitoring and decision-making, taking multiple aspects into account. In severe aphasia, there are additional demands. While still needing to perform all the usual linguistic and cognitive processing during communication, the PWSA simultaneously must find alternative ways to convey the message (e.g., gesture, writing, drawing, showing objects), decide what pieces of information should be prioritised when the message produced will be fragmented and evaluate the communication partner’s attempts at helpful guessing along the way (Penn, Frankel, Watermeyer, & Russell, 2010; Ramsberger, 2005). This process of “getting messages across in a variety of ways ranging from fully formed grammatical sentences to appropriate gestures” (Holland, 1982, p. 50) is labelled functional communication.

Rather strong (but not perfect) correlations between linguistic ability and functional communication have been found (Irwin, Wertz, & Avent, 2002; Lomas et al., 1989; Mazaux et al., 2013). There are also descriptions of vast individual differences (Holland, 1982; Ramsberger, 1994), and it is a common clinical observation that functional communication varies greatly in PWSA. Obviously, language is not the only factor that has an impact on functional communication. Executive function is one factor that has been investigated and found to play an important role (Fridriksson, Nettles, Davis, Morrow, & Montgomery, 2006; Murray, 2012; Purdy & Koch, 2006; Ramsberger, 2005).

Executive function is the part of human cognition responsible for general-purpose control processes, such as updating (monitoring and rapid addition/deletion of working-memory contents), shifting (switching flexibly between tasks or mental sets), and inhibition (deliberate overriding of dominant responses) (Miyake & Friedman, 2012). Executive functions are important for goal-directed behaviour, especially in novel circumstances as well as when decisions about behaviour must be made rapidly (Keil & Kaszniak, 2002; Toplak, West, & Stanovich, 2012).

Keil and Kaszniak (2002), in a review of materials for assessment of executive function in individuals with brain injury, divided the materials into four domains: planning/strategy use/rule use, fluency/generation/initiation, suppression/shifting, and abstract reasoning/concept formation. In this study, we will focus on the first three of these domains.
Measuring executive function is known to be difficult with the main reason being the “task impurity problem” (Friedman & Miyake, 2017), which refers to the difficulties in constructing tasks that engage executive functions without relying too heavily on other functions, such as visual processing, memory, language, and motor response. Assessing executive functions in PWSA poses additional challenges (H. El Hachioui et al., 2014; Keil & Kaszniak, 2002), since both instruction and performance need to have as little linguistic load as possible to ensure that the task measures the target skill and not, for example, comprehension of the instruction (Wall, Cumming, & Copland, 2017).

In stroke patients in general, impaired executive function is common (Rodrigues et al., 2018) and has a negative impact on quality of life, functional outcome and health-care costs (Cumming, Marshall, & Lazar, 2013). However, in many studies of cognition in stroke patients, PWA are excluded (Barnay et al., 2014; Wall et al., 2017). In studies specifically targeted on stroke patients with aphasia, findings indicate that executive impairments are common (H. El Hachioui et al., 2014; Murray, 2012). Since language and executive functions to some extent rely on neuroanatomically overlapping systems, the observation of problems with both in the same individual can be expected (Cahana-Amitay & Albert, 2015b; Keil & Kaszniak, 2002). There generally seems to be a relation between the severity of the aphasia and impairments in executive functions, but studies also consistently show that there are individuals for whom the two domains do not correlate (Murray, 2012; Nicholas, Hunsaker, & Guarino, 2017; Purdy & Koch, 2006).

Executive functions are related to functional communication (Fridriksson et al., 2006; Ramsberger, 2005) and cognitive flexibility, as an aspect of executive function, seems to be related to the ability to flexibly use different communication strategies (Purdy & Koch, 2006). Nicholas, Sinotte, and Helm-Estabrooks (2011) show that executive functions are more important than the severity of aphasia to the outcome of communication aid intervention.

To conclude, many studies of executive function and functional communication are performed with small samples including all severity levels of aphasia. We lack specific knowledge about the executive functions of PWSA as well as how they relate to linguistic ability and functional communication. Both scientific evidence and common sense indicate that better linguistic ability makes communication easier, but it is also a common clinical observation that among PWSA there is a large variation in functional communication that cannot be explained by linguistic ability alone. It could be hypothesised that communicating within the constraints of severe aphasia is especially demanding to executive functions. Functional communication is often measured only through rating scales, and raters (usually family members) might be partly unaware of the help and prompting they provide in communicative situations. Thus, a more objective, standardised measurement could provide additional information.

The aim of the present study was to expand understanding of the relations of executive functions and linguistic ability to functional communication in PWSA. To investigate this, it was necessary to establish first the presence of executive impairments in the group as well as whether these were related to linguistic ability.
The specific research questions were:

- To what extent do people with severe aphasia have impairments of executive functions?
- What is the relation between executive functions and linguistic ability?
- What are the relations of executive functions and linguistic ability to functional communication?

**Method**

To explore the relations between executive functions, linguistic ability, and functional communication in PWSA after stroke, we performed an observational study with a cross-sectional design.

**Participants**

Individuals with severe aphasia due to stroke were recruited through speech-language pathologists, patient organisations, and a folk high school (a Scandinavian form of liberal education for adults) in the central part of Sweden. It was a specific ambition to include people with very severe aphasia that are often excluded from research, thus mimicking the range of patients encountered in clinical practice.

**Inclusion criteria:**

- Stroke-induced aphasia, severity classified as a score within the range of 0–2 on the BDAE-3 Aphasia Severity Rating Scale (ASRS) (Goodglass, Kaplan, & Barresi, 2001);
- ≥6 months post stroke;
- Native speaker or equivalent of Swedish pre-stroke.

**Exclusion criteria:**

- Inability to participate in formal testing due to severe cognitive, motor, visual, or hearing impairments;
- Previous history of cognitive impairment.

Fifty-seven PWA were potentially eligible and agreed to an initial meeting after receiving brief information. One PWA refrained from participating. The remaining 56 were assessed: 7 of these were classified as ASRS 3 and 2 had traumatic brain injuries and thus did not meet the inclusion criteria. Ultimately, 47 PWSA were included.

For the purposes of this study, severe aphasia was defined as a score ≤2 on the ASRS. This estimation of aphasia severity was initially based on the informal conversation between the first author and the participant, and was conducted by the first author. Additional estimation was conducted from video recordings by the third author on 10 of the participants; an agreement of 90% was found regarding precise level of severity. Concerning inclusion in the study (i.e., ASRS ≤ 2), the agreement was 100%. These severity ratings were further confirmed with ASRS ratings based on the Comprehensive Aphasia Test (CAT) spoken picture description task and the CAT scores
on the same task. Information about hearing, vision, and level of competence in Swedish (for the one participant who had another native language) was collected from the participants and/or significant others. Information about the stroke was collected from medical records.

During data collection, it became clear that solving communication problems, both in informal conversation and formal assessment, differs considerably if you have some verbal (spoken or written) output, as opposed to if you have to rely solely on nonverbal communication. It was thus decided to divide the participants into verbal and nonverbal subgroups to form the basis for a more detailed analysis of the results. The principles for group designation will be explained below.

All participants had suffered one or more left hemisphere strokes that had caused the aphasia, and some participants had additional minor lesions in the right hemisphere.

Demographic data of the participants are shown in Table 1.

There were no differences between the verbal (n = 23) and the nonverbal (n = 24) subgroups regarding age, gender, handedness, level of education, time post onset, type, or number of strokes. The nonverbal subgroup had a significantly greater severity of aphasia and fewer had fluent aphasia in the nonverbal group.

### Table 1. Demographic data of participants, n = 47.

<table>
<thead>
<tr>
<th></th>
<th>Total sample (n = 47)</th>
<th>Verbal subgroup (n = 23)</th>
<th>Nonverbal subgroup (n = 24)</th>
<th>Difference between subgroups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (range)</td>
<td>64 (26–86)</td>
<td>64 (26–86)</td>
<td>65 (39–85)</td>
<td>( p = .856 ) ^a</td>
</tr>
<tr>
<td>Gender, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>( p = .813 ) ^b</td>
</tr>
<tr>
<td>Female</td>
<td>13 (27.7)</td>
<td>6 (26.1)</td>
<td>7 (29.2)</td>
<td>( p = .418 )^b</td>
</tr>
<tr>
<td>Male</td>
<td>34 (72.3)</td>
<td>17 (73.9)</td>
<td>17 (70.8)</td>
<td></td>
</tr>
<tr>
<td>Handedness, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>( p = .640 ) ^b</td>
</tr>
<tr>
<td>Right</td>
<td>40 (85.1)</td>
<td>19 (82.6)</td>
<td>21 (87.5)</td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>6 (12.8)</td>
<td>4 (17.4)</td>
<td>2 (8.3)</td>
<td></td>
</tr>
<tr>
<td>Ambidextrous</td>
<td>1 (2.1)</td>
<td>0</td>
<td>1 (4.2)</td>
<td></td>
</tr>
<tr>
<td>Education number of years, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>( p = .865 ) ^b</td>
</tr>
<tr>
<td>≤9 years</td>
<td>20 (42.6)</td>
<td>9 (39.1)</td>
<td>11 (45.8)</td>
<td></td>
</tr>
<tr>
<td>10–13 years</td>
<td>21 (44.7)</td>
<td>10 (43.5)</td>
<td>11 (45.8)</td>
<td></td>
</tr>
<tr>
<td>&gt;13 years</td>
<td>6 (12.8)</td>
<td>4 (17.4)</td>
<td>2 (8.3)</td>
<td></td>
</tr>
<tr>
<td>Months post stroke, mean (range)</td>
<td>81 (6–340)</td>
<td>77.3 (6–270)</td>
<td>85.8 (8–340)</td>
<td>( p = .710 ) ^a</td>
</tr>
<tr>
<td>Type of stroke, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>( p = .813 ) ^b</td>
</tr>
<tr>
<td>Ischaemic</td>
<td>30 (63.8)</td>
<td>15 (65.2)</td>
<td>15 (62.5)</td>
<td></td>
</tr>
<tr>
<td>Haemorrhagic</td>
<td>11 (23.4)</td>
<td>6 (26.1)</td>
<td>5 (20.8)</td>
<td></td>
</tr>
<tr>
<td>Both</td>
<td>5 (10.6)</td>
<td>2 (8.7)</td>
<td>3 (12.5)</td>
<td></td>
</tr>
<tr>
<td>Unknown</td>
<td>1 (2.1)</td>
<td>0</td>
<td>1 (4.2)</td>
<td></td>
</tr>
<tr>
<td>Number of strokes, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>( p = .813 ) ^b</td>
</tr>
<tr>
<td>One</td>
<td>34 (72)</td>
<td>17 (73.9)</td>
<td>17 (70.8)</td>
<td></td>
</tr>
<tr>
<td>Two or more^c</td>
<td>13 (28)</td>
<td>6 (26.1)</td>
<td>7 (29.2)</td>
<td>( p &lt; .001 ) ^b</td>
</tr>
<tr>
<td>Severity of aphasia ASRS, n (%)</td>
<td></td>
<td></td>
<td></td>
<td>( p = .006 ) ^b</td>
</tr>
<tr>
<td>0</td>
<td>4 (8.5)</td>
<td>0</td>
<td>4 (16.7)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>23 (49.0)</td>
<td>5 (21.7)</td>
<td>18 (75.0)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>20 (42.6)</td>
<td>18 (78.3)</td>
<td>2 (8.3)</td>
<td></td>
</tr>
<tr>
<td>Type of aphasia,^d n (%)</td>
<td></td>
<td></td>
<td></td>
<td>( p = .006 ) ^b</td>
</tr>
<tr>
<td>Nonfluent</td>
<td>35 (74.5)</td>
<td>13 (56.5)</td>
<td>22 (91.7)</td>
<td></td>
</tr>
<tr>
<td>Fluent</td>
<td>12 (25.5)</td>
<td>10 (43.5)</td>
<td>2 (8.3)</td>
<td></td>
</tr>
</tbody>
</table>

^a Mann–Whitney U-test.

^b Pearson chi-square test.

^c Of which four (9%) in addition had minor damage to the right hemisphere.

^d Rating of fluency according to Western Aphasia Battery (Kertesz, 2007).
The regional ethical review board of Uppsala approved the study (Dnr 2017/183).

**Material**

Below is a brief description of the assessments used to investigate executive function, linguistic ability, and functional communication. Detailed information about the materials can be found in Appendix 1.

**Executive functions**

Several assessment materials were reviewed in search of a valid measure of executive function with as little linguistic load as possible and that had not previously been shown to yield floor effects in populations with aphasia. Four subtests from the Cognitive Linguistic Quick Test (CLQT) (Helm-Estabrooks, 2001) were chosen, which are briefly described below.

**Symbol cancellation (CLQTsc).** Mainly assesses visuospatial skills and areas of visual field problems and/or neglect. In addition, it is stated to assess inhibition and response shifting (Helm-Estabrooks, 2001, 2002), which corresponds mainly to the domain of suppression/shifting of Keil and Kaszniak (2002) and is, based on this, included in this study. The score is the number of correct cancelled symbols minus incorrect cancelled symbols, which gives a maximum score of 12.

**Symbol trails (CLQTst).** Assesses working memory, planning, and mental flexibility (Helm-Estabrooks, 2001). This corresponds mainly to the domain of suppression/shifting of Keil and Kaszniak (2002). The score represents the number of correct lines with a maximum score of 10.

**Mazes (CLQTm).** Assesses planning, anticipating problems, and attention (Helm-Estabrooks, 2001), which corresponds mainly to the domain of planning/strategy use/rule use of Keil and Kaszniak (2002). Each successfully completed maze generates a score of 4, with points subtracted each time a line goes a ½ inch into a wrong path. Maximum score is 8.

**Design generation (CLQTdg).** Assesses productivity and creativity, ability to vary responses, self-monitor, and use effective strategies (Helm-Estabrooks, 2001). This corresponds mainly to the domain of fluency/generation/initiation of Keil and Kaszniak (2002). The score is the number of designs generated minus perseverated, copied, and incorrect designs. The maximum score is 13.

The scores of the four subtests of CLQT were summed to give a CLQT total (CLQTtot) with a maximum score of 43.

Criterion cut scores based on two age intervals (18–69 and 70–89) are provided in the CLQT. Performance at or above the cut score is considered within normal limits. To make comparison across groups and subtests possible, a transformed score was calculated by subtracting the relevant criterion cut score from the raw score for each participant, resulting in a figure expressing how many points below or above cut an individual performs (Helm-Estabrooks, 2002). Performance exactly at cut score thus generates a transformed score of 0.
When comparing executive functions to other variables in this study, the absolute level of performance was considered most interesting; thus, CLQT raw scores were used in all correlation analyses.

**Linguistic ability**
Linguistic ability was measured with the language battery from the Comprehensive Aphasia Test (CAT) (Swinburn, Porter, & Howard, 2004), which includes spoken and written language comprehension and production.

To reduce the amount of data, three composite scores were assembled from the CAT scores. A language comprehension score consisting of all subtests for comprehension of spoken and written material was calculated and labelled language comprehension (LC). Maximum LC score was 128. For expression, a score reflecting the verbal output functions directly relevant to functional communication was desired. Thus, a composite score consisting of all subtests demanding independent accessing and production of spoken or written verbal output (naming objects, naming actions, word fluency, spoken picture description, writing picture names and written picture description) was calculated. This score was labelled verbality index (VI). Maximum VI score was 99 + word fluency (a task for which a maximum score is not defined). Finally, a total score was calculated consisting of all the subtests of the CAT language battery. The maximum score of CATtot is 406 + word fluency.

**Functional communication**
Considering the multifaceted nature of functional communication, it was decided to use two different measures: formal testing with the Scenario test (van der Meulen, van de Sandt-Koenderman, Duivenvoorden, & Ribbers, 2010) and rating by a significant other with the Communicative Effectiveness Index (Lomas et al., 1989).

**Scenario test (ST).** The ST (van der Meulen et al., 2010) was developed to measure objectively the multi-modal communication of people with moderate to severe aphasia in an interactive setting with a supportive communication partner. During the ST, the PWA is presented with everyday scenarios and asked to convey a specific message within that situation (e.g., to ask a waiter for the menu at a restaurant). Any mode of communication is accepted. The maximum score of the ST is 54.

**Communicative effectiveness index (CETI).** CETI was developed to measure the performance of functional communication in daily living rated by a significant other (Lomas et al., 1989). CETI uses 100 mm visual analogue scales where the significant other rates the PWA’s performance in 16 different communication situations. The mean of the 16 items is calculated, which gives a maximum score of 100. A higher score indicates better communicative performance.
Procedure
All assessments were performed by the first author during the period August 2017–June 2018. For most participants, the assessments took place in their homes, but in four cases this occurred at another location where the participant felt at ease. A significant other was allowed to be present during the assessments if the participant wished. In those cases, the first author attempted to ensure this did not interfere with the assessment procedure. Assessments took 2–4 h in total, distributed over 2–4 occasions depending on the time needed and the stamina of the participant. The occasions were spread over a period of 6–98 days (median 21), planned according to the preferences of the participant and practical issues. This meant that for some participants the period over which testing was conducted was long. However, inclusion criteria were such that participants were in a chronic stage of aphasia and dramatic linguistic improvements were thus unlikely. Data for an additional study were collected at the same time. The CAT was the first assessment performed, followed by the CLQT and lastly the ST. The distribution of the assessments over the occasions varied depending on the time needed for each participant to complete the assessments. CAT typically took the whole first session, and for many also part of the second. Since the CLQT subtests are few, short and performed with a time limit they are particularly sensitive to temporary fluctuations in attention, which are common in PWA (Villard & Kiran, 2018). For this reason, the investigator took special care to ensure the CLQT was not performed when the participant was already tired from other assessments. The complete assessment procedure was video recorded.

A significant other completed the CETI.

Statistical analysis
Statistical analyses were performed using IBM SPSS versions 24 and 25. Preliminary inspection of the data revealed a non-normal distribution of most of the variables and a nonlinear relationship between some of the variables. It was thus decided to use nonparametric methods for all statistical analyses. In addition to analysing the whole sample, the participants were divided into two subgroups based on verbal output ability. The cut off for subgroup designation was based on clinical judgement and inspection of the distribution of VI scores. Participants with VI ≤ 10 were labelled nonverbal, the others as verbal. This resulted in 23 participants in the verbal and 24 in the nonverbal subgroup.

To compare the demographic data of the two subgroups, the Mann–Whitney U-test was used for continuous data and chi-2 test for categorical data. For comparing the subgroups’ raw scores on CLQT and CAT, the Mann–Whitney U-test was used. For bivariate correlations, Spearman’s rank correlations were used. For analysis of the relations of executive functions and linguistic ability with functional communication, bivariate correlations were insufficient because of moderate to strong correlations between the executive functions and linguistic ability. Thus, to study the different variables’ unique relation to functional communication, Spearman’s partial rank correlations were calculated for each variable, while controlling for the others. Cohen’s (1988) guidelines for interpretation of correlation coefficients were adopted (.10–.29 = small, .30–.49 = medium, .50–1.00 = large).

A significance level of .01 (two-tailed) was adopted because of multiple comparisons. Significant values are indicated in bold text and exact p-values are presented.
Results

Executive functions

There were no significant correlations between executive functions and age, gender, handedness, level of education, time postonset, or type or number of strokes.

Raw scores for the total sample and subgroups are presented in Table 2 along with the analysis of the difference in performance between the two groups. There was a significant difference between the subgroups on the subtests symbol trails and design generation as well as on the CLQTtot. The difference regarding symbol cancellation approached significance.

Table 3 presents the median transformed scores for the total sample and subgroups, as well as number and percent of participants performing below criterion cut scores. In the total sample, 40 participants (85%) performed below cut score on CLQTtot. Of the seven participants performing above cut score, three were in the non-verbal subgroup. Of the different subtests, symbol trails and design generation seem to be the most difficult with 63% and 68% of the participants, respectively, performing below cut score in the total sample.

Transformed scores were used only for comparison to the criterion cut scores provided in CLQT. In all the following analyses raw scores were used, since actual performance was considered most relevant.

### Table 2. Results of the CLQT, raw scores for total sample and subgroups.

| Task (total possible score) (Criterion cut score 18–69 years, 70–89 years) | Median raw score | Total sample (n = 47), median raw score (interquartile range) | Verbal (n = 23), median raw score (interquartile range) | Non-verbal (n = 24), median raw score (interquartile range) | Difference between subgroups*
|---|---|---|---|---|---|
| Symbol cancellation (12) (11, 10) | 10 (3–12) | 11 (8–12) | 4 (0.25–11) | $U = 389.5$ | $p = .014$
| Symbol trails (10) (9, 6) | 6 (2–9) | 8 (4–10) | 2 (1–6) | $U = 425$ | $p = .001$
| Mazes (8) (7, 4) | 4 (4–8) | 7 (4–8) | 4 (3.25–7) | $U = 370$ | $p = .033$
| Design generation (13) (6, 5) | 3 (1–5) | 5 (3–6) | 2 (1–4) | $U = 426.5$ | $p = .001$
| CLQTtotal (43) (33, 25) | 24 (11–32) | 31 (24–32) | 14.5 (7.25–25.5) | $U = 440$ | $p \leq .001$

*Mann-Whitney U test

### Table 3. Results of the CLQT, transformed scores for total sample and subgroups, comparison to criterion cut scores.

<table>
<thead>
<tr>
<th>Task (total possible score)</th>
<th>Median transformed score (IQR)</th>
<th>No (%) below cut score</th>
<th>Median transformed score (IQR)</th>
<th>No (%) below cut score</th>
<th>Median transformed score (IQR)</th>
<th>No (%) below cut score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbol cancellation (12)</td>
<td>$-1 (-7–1)$</td>
<td>25 (53)</td>
<td>$-5 (-10–1)$</td>
<td>13 (56)</td>
<td>$-5 (-3.5–1)$</td>
<td>12 (50)</td>
</tr>
<tr>
<td>Symbol trails (10)</td>
<td>$-2 (-7–1)$</td>
<td>30 (63)</td>
<td>$-3 (-7–1)$</td>
<td>15 (65)</td>
<td>$-2 (-6.75–1)$</td>
<td>15 (62)</td>
</tr>
<tr>
<td>Mazes (8)</td>
<td>$0 (-3–1)$</td>
<td>22 (46)</td>
<td>$0 (-3–1)$</td>
<td>11 (48)</td>
<td>$0 (-3–1)$</td>
<td>11 (46)</td>
</tr>
<tr>
<td>Design generation (13)</td>
<td>$-2 (-4–0)$</td>
<td>32 (68)</td>
<td>$-3 (-4–0)$</td>
<td>16 (70)</td>
<td>$-2 (-3–0)$</td>
<td>16 (67)</td>
</tr>
<tr>
<td>CLQTtotal (43)</td>
<td>$-7 (-17–1)$</td>
<td>40</td>
<td>$-13$</td>
<td>19</td>
<td>$-5.5$</td>
<td>21</td>
</tr>
</tbody>
</table>
To further investigate the relations to other samples, raw scores of the participants of the present study were compared to the left-hemisphere injured clinical sample of Helm-Estabrooks (2001) with a one-sample \( t \)-test. It would be expected that the participants of the present study perform equal to or somewhat lower (being specifically a sample of people with severe aphasia) than the clinical sample of Helm-Estabrooks (2001). There were no significant differences for symbol trails, mazes, design generation, or CLQTtot. For symbol cancellation, the difference came close to significance \((t(46) = -2.65, p = .011)\) in which participants of this study performed slightly worse with a raw score median of 7.5 compared to 9.3 in the sample of Helm-Estabrooks (2001). Thus, the participants of this study perform as could be expected based on previous studies.

**Linguistic ability**

There were no significant correlations between linguistic ability and age, gender, handedness, level of education, time postonset, or type or number of strokes. Spearman’s rank correlation between ASRS ratings and CATtot scores was \( r_s = .80 \) \((p = .001)\).

Results on the language battery of the CAT are presented in Table 4.

There is a wide distribution of LC, whereas the VI is generally low. There are also some participants with relatively high CATtot scores. The difference between the subgroups is significant for all linguistic measures (Mann–Whitney U-test, all \( p \leq .001\)).

**Functional communication**

There were no significant correlations between ST or CETI and age, gender, handedness, level of education, time postonset, or type or number of strokes.

Results on ST and CETI are presented in Table 5. The verbal subgroup had significantly higher scores than the non-verbal on both measures.

A moderate correlation approaching significance was found between the ST and the CETI for the total sample \((r_s = .35, p = .018)\).

### Table 4. Results of the CAT, total sample, and subgroups.

<table>
<thead>
<tr>
<th></th>
<th>Median (interquartile range)</th>
<th>Difference between subgroups(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total sample ( n = 47 )</td>
<td>Verbal subgroup ( n = 23 )</td>
</tr>
<tr>
<td><strong>Language comprehension</strong> (max 128)</td>
<td>73 (38–91)</td>
<td>91 (73–96)</td>
</tr>
<tr>
<td><strong>Verbality index</strong> (max 99(^a))</td>
<td>7 (0–30)</td>
<td>30 (17–47)</td>
</tr>
<tr>
<td><strong>CAT total</strong> (max 406(^a))</td>
<td>121 (55–212)</td>
<td>212 (153–230)</td>
</tr>
</tbody>
</table>

\(^a\)This is the total predefined possible score. Additional scores can be obtained in the task of word fluency, where a maximum score is not defined. Median number of words produced for participants was 1 (interquartile range 0–4).

\(^b\)Mann–Whitney U-test

\(^c\)The group designation is based on VI scores, thus a significant difference between the groups in this variable is self-evident.
Relation between executive function and linguistic ability

Correlation coefficients between linguistic measures and scores on the CLQT fall between $r_s = .37$ (VI and CLQTst) and $r_s = .70$ (LC and CLQTtot), all being significant (Table 6).

For the two subgroups, there are fewer significant correlations, but the pattern with the strongest correlations appearing with LC and CATtot seen for the total sample, remains in the subgroups (Table 7).

Table 5. Results of the ST and CETI, total sample, and subgroups.

<table>
<thead>
<tr>
<th></th>
<th>Median (interquartile range)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total sample</td>
<td>Verbally subgroup</td>
</tr>
<tr>
<td>Scenario Test (max 54)</td>
<td>37.5 (16–46)</td>
<td>44 (40–51)</td>
</tr>
<tr>
<td>CETI (max 100)</td>
<td>41.6 (30.9–56.7)</td>
<td>54.2 (42.8–62.1)</td>
</tr>
</tbody>
</table>

$^a$Mann-Whitney U-test

Table 6. Total sample (n= 47) Spearman’s rank correlations between linguistic ability (LC, VI, CATtot) and executive functions (CLQT subtests and total score) p-values in parentheses. Significant correlations (p ≤ .01) are indicated in bold text.

<table>
<thead>
<tr>
<th></th>
<th>CLQTsc</th>
<th>CLQTst</th>
<th>CLQTm</th>
<th>CLQTdg</th>
<th>CLQTtot</th>
</tr>
</thead>
<tbody>
<tr>
<td>LC</td>
<td>.45 (.001)</td>
<td>.61 (&lt;.001)</td>
<td>.59 (&lt;.001)</td>
<td>.60 (&lt;.001)</td>
<td>.70 (&lt;.001)</td>
</tr>
<tr>
<td>VI</td>
<td>.44 (.002)</td>
<td>.37 (.010)</td>
<td>.39 (.006)</td>
<td>.52 (.001)</td>
<td>.55 (.001)</td>
</tr>
<tr>
<td>CATtot</td>
<td>.47 (.001)</td>
<td>.45 (.001)</td>
<td>.46 (.001)</td>
<td>.58 (.001)</td>
<td>.61 (.001)</td>
</tr>
</tbody>
</table>

LC = language comprehension, VI = verbality index, sc = symbol cancellation, st = symbol trails, m = mazes, dg = design generation, tot = total

Table 7. Verbal (n= 23) and non-verbal (n= 24) subgroups. Spearman’s rank correlations between linguistic ability (LC, VI, CATtot) and executive functions (CLQT subtests and total score). P-values in parentheses. Significant correlations (p ≤ .01) are indicated in bold text.

<table>
<thead>
<tr>
<th></th>
<th>CLQTsc</th>
<th>CLQTst</th>
<th>CLQTm</th>
<th>CLQTdg</th>
<th>CLQTtot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal</td>
<td>LC</td>
<td>.29 (.176)</td>
<td>.54 (.007)</td>
<td>.47 (.025)</td>
<td>.55 (.006)</td>
</tr>
<tr>
<td></td>
<td>VI</td>
<td>.30 (.157)</td>
<td>-.26 (.222)</td>
<td>.06 (.774)</td>
<td>.33 (.127)</td>
</tr>
<tr>
<td></td>
<td>CATtot</td>
<td>.39 (.067)</td>
<td>-.17 (.453)</td>
<td>.06 (.777)</td>
<td>.40 (.061)</td>
</tr>
<tr>
<td>Non-verbal</td>
<td>LC</td>
<td>.30 (.160)</td>
<td>.39 (.061)</td>
<td>.60 (.002)</td>
<td>.40 (.056)</td>
</tr>
<tr>
<td></td>
<td>VI</td>
<td>.25 (.231)</td>
<td>.08 (.703)</td>
<td>.47 (.285)</td>
<td>.23 (.285)</td>
</tr>
<tr>
<td></td>
<td>CATtot</td>
<td>.36 (.080)</td>
<td>.32 (.123)</td>
<td>.68 (&lt;.001)</td>
<td>.42 (.039)</td>
</tr>
</tbody>
</table>

LC = language comprehension, VI = verbality index, sc = symbol cancellation, st = symbol trails, m = mazes, dg = design generation, tot = total
Relations of executive functions and linguistic ability to functional communication

For correlation analyses, CLQTtot was used as the measure of executive function; LC and VI were used as measures of linguistic ability. The one participant who did not complete the ST was excluded from the parts of the correlation analyses having ST as a variable. Bivariate correlations between executive function, linguistic ability and functional communication are presented in Table 8.

For the ST, there were strong correlations with measures of executive function (CLQTtot) and linguistic ability (both LC and VI) in the total sample and the nonverbal subgroup, but no significant correlations in the verbal subgroup. For CETI, there were moderate to strong correlations with executive function and linguistic ability in the total sample, no significant correlations in the verbal subgroup and significance only for the correlation between CETI and VI in the nonverbal subgroup.

Considering the strong correlations between executive function and linguistic ability (Table 6), partial correlations between those variables and the measures of functional communication (ST and CETI) were calculated to investigate the different variables’ unique relations. Results of the partial correlation analysis are presented in Table 9.

In the total sample, VI shows a moderate partial correlation with the ST, which gives an $R^2$ value of .21, indicating that VI shares 21% of the variance in the ST. For the CETI, there is a partial correlation with VI, indicating 26% shared variance.

For the verbal subgroup, none of the partial correlations was significant. In the nonverbal subgroup, there was a strong correlation between CLQTtot and the ST,

### Table 8. Bivariate Spearman’s rank correlation coefficients of CLQTtot, LC, and VI with the ST and CETI. Total sample and subgroups. P-values in parentheses. Significant correlations ($p \leq .01$) are indicated in bold text.

<table>
<thead>
<tr>
<th></th>
<th>Total sample (n = 46 for ST, n = 47 for CETI)</th>
<th>Verbal subgroup (n= 23)</th>
<th>Nonverbal subgroup (n= 23 for ST, n = 24 for CETI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLQTtot</td>
<td>.64 (&lt;.001)</td>
<td>.34 (.113)</td>
<td>.71 (&lt;.001)</td>
</tr>
<tr>
<td>LC</td>
<td>.77 (&lt;.001)</td>
<td>.48 (.020)</td>
<td>.63 (.001)</td>
</tr>
<tr>
<td>VI</td>
<td>.77 (&lt;.001)</td>
<td>.39 (.070)</td>
<td>.58 (.004)</td>
</tr>
<tr>
<td>CETI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLQTtot</td>
<td>.42 (.004)</td>
<td>.20 (.360)</td>
<td>.29 (.172)</td>
</tr>
<tr>
<td>LC</td>
<td>.44 (.002)</td>
<td>−.15 (.500)</td>
<td>.31 (.136)</td>
</tr>
<tr>
<td>VI</td>
<td>.63 (&lt;.001)</td>
<td>.16 (.468)</td>
<td>.57 (.004)</td>
</tr>
</tbody>
</table>

### Table 9. Spearman’s partial rank correlation coefficients of CLQTtot, LC, and VI with the ST and CETI. Total sample and subgroups. P-values in parentheses. Significant correlations ($p \leq .01$) are indicated in bold text.

<table>
<thead>
<tr>
<th></th>
<th>Total sample (n = 46 for ST, n = 47 for CETI)</th>
<th>Verbal subgroup (n= 23)</th>
<th>Nonverbal subgroup (n= 23 for ST, n = 24 for CETI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLQTtot$^a$</td>
<td>.26 (.089)</td>
<td>.01 (.958)</td>
<td>.59 (.005)</td>
</tr>
<tr>
<td>LC$^b$</td>
<td>.32 (.034)</td>
<td>.40 (.074)</td>
<td>.32 (.163)</td>
</tr>
<tr>
<td>VI$^c$</td>
<td>.46 (.002)</td>
<td>.37 (.103)</td>
<td>.34 (.129)</td>
</tr>
<tr>
<td>CETI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLQTtot$^a$</td>
<td>.18 (.245)</td>
<td>.33 (.141)</td>
<td>.10 (.649)</td>
</tr>
<tr>
<td>LC$^b$</td>
<td>−.16 (.294)</td>
<td>−.33 (.140)</td>
<td>−.06 (.788)</td>
</tr>
<tr>
<td>VI$^c$</td>
<td>.51 (&lt;.001)</td>
<td>.12 (.594)</td>
<td>.49 (.021)</td>
</tr>
</tbody>
</table>

$^a$controlling for LC and VI
$^b$controlling for VI and CLQTtot
$^c$controlling for LC and CLQTtot
which gives an $R^2$ value of .35, indicating that CLQTtot shares 35% of the variance in the ST. With the CETI, no significant partial correlations were found in the nonverbal subgroup.

Scatterplots were made to visualise the variation of functional communication, executive function and linguistic ability among PWSA. In Figure 1(a–d), VI is plotted on the x-axis, with a vertical line indicating the cut off between the verbal (to the right of the line) and the nonverbal subgroup (to the left). The axis is adjusted to the distribution in the sample, and the maximum possible score of VI is 99 + word fluency.

Figure 1(a) shows VI plotted against CLQTtot. There is variation along almost the whole range of CLQT scores in both subgroups.

Figure 1(b) shows VI plotted against LC. We find a large variation of LC in the nonverbal subgroup, with the highest scores reaching well within the range of the verbal subgroup.

In Figure 1(c,d), VI is plotted against the ST and CETI, respectively. As seen in Figure 1(c) there is limited variation in ST scores in the verbal subgroup and no clear relationship with VI. In the nonverbal subgroup, there is a large variation in ST scores but again no clear relation to VI. The scatterplot with the CETI (Figure 1(d)) reveals a somewhat different

![Figure 1](image-url)

**Figure 1.** Verbality index (maximum score 99) on all x-axes. Vertical lines indicating the cut off between the verbal (to the right) and the nonverbal subgroup (to the left). (a) Y-axis shows CLQT total raw score (maximum score 43). (b) Y-axis shows CAT language comprehension (maximum score 128). (c) Y-axis shows Scenario Test scores (maximum score 54). (d) Y-axis shows CETI scores (maximum score 100).
situation. Here, both subgroups show large variation and the nonverbal subgroup does not vary along the whole range of CETI scores.

Discussion

The aim of this study was to examine the relationships between executive function, linguistic ability, and functional communication in PWSA after stroke. Severe aphasia was, for the purpose of this study, defined as a score in the range between 0–2 on ASRS, which results in a rating mainly focusing on verbal output. Even within this population, observations during data collection suggested a need to also analyse the participants in two subgroups based on the amount of verbal (spoken and written) output they were able to produce. Data analysis was thus conducted both on the total sample and on a verbal and a non-verbal subgroup. Our findings confirm that impairments of executive function are common in this population. There were moderate to strong correlations between all the measures of executive function and linguistic ability. For the total sample, verbal output strongly correlated with functional communication. In the non-verbal subgroup, executive function was strongly correlated with functional communication. In addition, we found large variation regarding LC, executive function and functional communication, especially in the nonverbal subgroup. For the verbal participants, we found no significant partial correlations between executive functions or linguistic ability and functional communication.

Each of the research questions will be discussed in greater detail below.

To what extent do people with severe aphasia have impairments of executive functions?

Using four subtests from the CLQT, we found a large proportion of our sample (85%) performs below cut score for normal performance. Finding executive dysfunction in this group, where most participants have suffered extensive strokes, is expected considering the anatomical overlapping of systems serving linguistic and executive functions (Cahana-Amitay & Albert, 2015a; Keil & Kaszniak, 2002). As a group, the nonverbal participants had more severe impairments of executive functions.

What is the relation between executive functions and linguistic ability?

We found moderate to strong correlations between all parts of the CLQT and all measures of linguistic ability, confirming findings of relations between language and executive (and other cognitive) functions in previous studies (Fucetola, Connor, Strube, & Corbetta, 2009; Murray, 2012, 2017; Nicholas et al., 2017) while contradicting others (Helm-Estabrooks, 2002). A possible explanation for the relation in our participants could be that it is an artefact of their impaired LC, causing problems understanding the CLQT task instructions. There is undeniably a strong correlation between the CLQT and LC, which could support this explanation. However, one might then expect a stronger relationship between LC and the CLQT subtests that have the most complex instructions. This would refer to design generation in our set of subtests, as compared to, for instance, mazes, which is a task much easier to comprehend. For these two subtests, we
find almost exactly the same correlation coefficients with LC ($r_s = .60 \ p = .001$ for design generation and $r_s = .59 \ p = \leq .001$ for mazes) in the total sample. In the nonverbal subgroup, LC correlated significantly with mazes ($r_s = .60 \ p = .002$) but not with design generation ($r_s = .40 \ p = .056$); hence, the opposite relationship to what would be expected if comprehension of verbal instructions was the main explanation for the correlations between LC and CLQT scores. Finally, Lacey, Skipper-Kallal, Xing, Fama, and Turkeltaub (2017) performed a factor analysis to investigate a number of assessments used with PWA, including the executive parts of the CLQT. Their results show that the executive CLQT subtests load primarily on an executive factor, with only a small loading on the comprehension factor. There are several other possible interpretations of the correlations between executive function and linguistic ability in our sample, perhaps the most obvious being neuroanatomically caused co-occurrence, since larger strokes tend to cause larger impairments in both language and cognition (Cahana-Amitay & Albert, 2015b; Robert Fucetola et al., 2009; Keil & Kaszniak, 2002). Further, some researchers view aphasia symptoms partly as effects of executive dysfunction (Martin & Allen, 2008), whereas others hypothesise that severely damaged language functions have detrimental effects on executive functions (Baldo et al., 2005). Both these hypotheses predict correlations such as the ones seen in our results. The results of this study confirm that executive function and linguistic ability are related. However, as seen in Table 9, linguistic ability and executive function seem to relate in unique ways to functional communication in the two subgroups, which indicates that the two variables represent at least to some degree different constructs.

**What are the relations among executive function, linguistic ability, and functional communication?**

As expected, the nonverbal participants showed greater limitations of functional communication than the verbal subgroup on both formal test (ST) and ratings made by significant others (CETI).

The ST and CETI represent two very different approaches to measuring functional communication, which is also illustrated by the moderate correlation approaching significance that was found between the two measures ($r_s = .35, \ p = .018$). The ST is based solely on the performance in the specific context of the test administration. It mediates a picture of the participant’s objective communicative ability with a “standardised” communication partner. The CETI, on the other hand, is intended to capture the effectiveness of the communicative acts that the individual actually performs in everyday life. This encompasses several communicative activities that the ST does not cover, such as starting conversations or having conversations with friends and neighbours. Another important difference between the two instruments is that the ST is developed for PWSA, whereas the CETI is intended for aphasia of all severity levels. van der Meulen et al. (2010) found a moderate ($r = .50$) significant correlation between ST and CETI in their sample of 122 individuals covering all severity levels of aphasia. They too divided their sample into a verbal and a non-verbal subgroup, finding the correlation in the verbal subgroup to be .36 whereas in the non-verbal subgroup the correlation did not reach significance. Performing statistical analyses on data from ratings using
visual analogue scales is somewhat precarious, but our data seem to yield results similar to those of van der Meulen et al. (2010).

Having measured functional communication in two different ways, we moved on to the main question of the relations of executive functions and linguistic ability to functional communication. In the total sample, we found that executive function, LC and VI all had moderate to strong bivariate correlations with both measures of functional communication (ST and CETI), as seen in Table 8. However, given the strong correlations between linguistic ability and executive function, the bivariate correlations are difficult to interpret. Instead, partial correlations were calculated to investigate the unique relations between the different variables whilst controlling for the others (Table 9). In the total sample, VI was the only variable with a significant partial correlation with functional communication, when controlling for LC and executive function. Or, to put it simpler, the better the participants speak (and/or write), the better they communicate. Finding out that ability for verbal output is important for functional communication is hardly surprising and has been shown previously (Fucetola & Tabor Connor, 2015; Lomas et al., 1989; Mazaux et al., 2013).

However, when analysing the verbal and nonverbal subgroups separately, another picture emerges. In the nonverbal subgroup, CLQT was the only variable with a significant partial correlation with functional communication, when controlling for LC and VI. This indicates that when verbal output is severely limited or completely absent, executive function is indeed one important resource needed in the attempts to find alternative ways to get the message across, as hypothesised. The results shown in Figure 1(c) could also indicate that for nonverbal PWSA, even a small improvement in verbal output can have an important effect on functional communication. Regarding the CETI for the nonverbal subgroup, we found no relation with executive functions or LC. Nor was the correlation with VI significant with the significance level adopted here ($r_s = .49, p = .021$).

In the verbal subgroup, none of the measures included in the partial correlation analysis managed to capture factors that had a unique significant relationship with functional communication. This result is somewhat surprising, but Figure 1(c) might offer an explanation. It is clear from Figure 1(c) that there is an increase in ST scores with increasing VI. However, the two subgroups look very different from each other. This is likely due to the fact that with a little bit of verbal output the tasks in ST are not very challenging, allowing all the verbal participants to achieve relatively high scores. Without verbal output, the tasks are more challenging, which creates room for greater variation in the nonverbal subgroup.

The results should not be interpreted as if executive functions are not important to the communication of people with some verbal output. For those, an impairment might be evident in more challenging communicative tasks, such as discourse, as has been suggested by Frankel, Penn, and Ormond-Brown (2007); Henderson, Kim, Kintz, Frisco, and Wright (2017); and Penn et al. (2010), among others. Regarding the CETI, we saw no correlations with executive functions in either of the subgroups. Since the tool is completed by people close in everyday life, it is likely that the CETI ratings are mainly based on experience from situations relatively recurrent and familiar to the PWSA, which does not put as much strain on executive function.
There is a risk that the correlation between the ST and executive function simply reflects unintentional demands on executive function in the task design of the ST. The situations used in the ST are not in themselves unusual or particularly complex (i.e., asking the taxi driver for a receipt or explaining to your doctor that you have a cough). However, many of our participants are not put in these situations without company in their day-to-day lives, which means they are rarely left to deal with such issues on their own. And even if so, complex aspects are added by the test situation, which demands to communicate in an unnatural context, having to pretend to be in the situations described. It might be a very different task to figure out how to ask for a spoon at the restaurant when you actually experience the need for a spoon, rather than having to pretend you need one. Yet again, while such real-life situations can trigger great resourcefulness for some individuals, they can be stressful and thwarting to others. The scores of the ST could be said to reflect the independence with which the PWSA conveys the messages. Equally high scores are given if you manage to get the message across on the first attempt, as if you fail on the first attempt but then without prompting successfully shift to another communication mode. Scores are reduced when prompting is needed. Monitoring of performance, generating strategies and shifting between them are likely to be crucial skills in the ST for PWSA who have no verbal output, just as in communication in everyday situations. Our results indicate that the ST is indeed a test demanding executive functions for individuals with severely limited verbal output, and we think there is a good reason to conclude that those demands reflect some of the demands put on the individual while trying to communicate in an unfamiliar situation.

PWA are often judged in society by their ability to speak. Inspection of Figure 1(a–d) shows large variation in LC, executive function and functional communication in the nonverbal group. In fact, for all measures except the ST, the highest score is gained by a participant in or very close to the nonverbal group. Thus, among PWSA with no verbal output, it can be expected to find individuals who have good LC, good executive functions and who are skilled communicators.

Clinical relevance

When encountering patients with severe aphasia, it is important to consider that many struggle with executive dysfunction, which is likely to interfere with many aspects of their everyday life, including the ability to use available means for communication to their full potential. Executive dysfunction is known to interfere with the ability to benefit from intervention (Simic, Rochon, Greco, & Martino, 2019) and has been shown to be a predictor of lower levels of quality of life (Nicholas et al., 2017). There is a strong correlation between executive function and linguistic ability; however, it would be a mistake to assume that all patients with severe aphasia also have severe executive dysfunction. Our results show that even in the participants with the most severely restricted verbal output, executive functions vary greatly. It is therefore important to obtain the best possible evaluation of executive (and other cognitive) functions, even though standard test procedures and materials can be a challenge in this population. Executive functions are important to functional communication, and this must be considered in interventions.
Methodological considerations

Some participants have rather high CATtot scores, which might be surprising considering the focus of the study was PWSA. The explanation for this is that the ASRS, which was used for aphasia severity rating, puts emphasis on expression. It is common to classify 0–2 of ASRS as severe aphasia (e.g., Darrigrand et al., 2011; Koleck et al., 2017; W. M. Van de Sandt-Koenderman, J. Wiegers, S. M. Wielant, H. J. Duivenvoorden, & G. M. Ribbers, 2007). A rating of 2 is defined as “Conversation about familiar subjects is possible with help from the listener. There are frequent failures to convey the idea, but the patient shares the burden of communication”. However, there is quite a leap to the next level, which is commonly referred to as moderate aphasia. A rating of 3 is defined as “The patient can discuss almost all everyday problems with little or no assistance. Reduction of speech and/or comprehension, however, makes conversation about certain material difficult or impossible”. The ASRS rating can thus be low even if the person has good comprehension. A few participants also had well preserved repetition, which generates many points to the CAT total score, but represents an ability that is of little use in the informal conversation on which the ASRS rating was based. Since our participants had ASRS ratings of 0–2, they were labelled as having severe aphasia, but the reader should be aware that some of the participants who just failed to be classified as 3 have aphasias that could be perceived as moderate. Even though the use of ASRS leads to a wide definition of severe aphasia, it was preferred before a quantitative definition tied to linguistic test results, based on the fact that the focus of interest for this study was functional communication and in that context a severity classification that simulates the communication partners’ perception of the communication problems seemed most relevant.

It is likely that many of the participants have apraxia of speech in addition to the aphasia. Apraxia of speech is “an acquired disorder of learned volitional actions associated with a breakdown in the planning or programming of the movements needed for speech” (Miller & Wambaugh, 2017, p. 493) and it frequently co-occurs with aphasia. No formal assessment of apraxia of speech was included in this study. Differentiating between apraxia of speech and aphasia relies heavily on analysing speech errors (Strand, Duffy, Clark, & Josephs, 2014), which was impossible with many of the participants. Severe apraxia of speech without aphasia is rare (Miller & Wambaugh, 2017). Nonetheless, since our inclusion criterion regarding the severity of aphasia was based on the ASRS there is a small risk of accidentally including someone with mild aphasia but severe apraxia of speech. However, such individuals would be expected to have both good writing and comprehension, which is not the case with any of our participants.

The cut-off between the subgroups could be argued to be somewhat arbitrary. All participants experience extensive difficulties regarding verbal expression. However, observations during data collection indicated that interesting information might be lost by treating the sample as one homogenous group. The participants who were classified as nonverbal truly had no means of intelligible verbal (spoken or written) output. The participants classified as verbal all have a little bit of verbal output that serves as an important communication channel for them, even if it is very limited. For several participants, the verbal output was restricted to writing single words or parts of words. It should be remembered that verbal participants who have VI scores close to cut
off face immense communicative challenges too. After setting the cut off to a VI of 10, we noted that it generated subgroups of equal size, a fact that further spoke in favour of the chosen cut off.

In all cases, the aphasia had been caused by a left hemisphere stroke. Four participants (9%) had additional minor damages to the right hemisphere. None of them showed any obvious clinical signs of right hemisphere injury. It was decided to include these participants since in clinical practice it is not uncommon that patients with severe aphasia have gone through several strokes and often in both hemispheres. It cannot be ruled out that the right hemisphere injuries had an impact on performance. However, the precise location of the injury does not invalidate the relations between executive function and functional communication in the individual.

Regarding the CLQT subtests used to assess executive function, it should be noted that all the tasks rely heavily on visuospatial perception and processing, which is a common (and possibly inevitable) characteristic of non-verbal assessments of executive function (Simic et al., 2019). As many PWSA also have some impairments of visuospatial processing, navigating among possible assessments becomes a matter of finding the least bad choice of material. Considering the participants of this study, using non-linguistic assessments was deemed more important than avoiding visuospatial demands.

The use of the CLQT criterion cut scores is insufficient if one aims for an in-depth analysis of the presence and precise level of executive dysfunction in PWSA. For such a study, a control group would have been necessary. However, this was considered beyond the scope of the present study, since the main purpose was to investigate the relations of executive function and linguistic ability to functional communication.

**Further research**

According to our results, the executive function does have a relation to functional communication in severe aphasia. Can this knowledge be used to better help our patients? How can intervention be designed to target the executive dysfunctions that have an impact on functional communication? Several attempts have been made (an excellent overview can be found in Mayer, Mitchinson, and Murray (2017)) but rarely with a focus on PWSA. A promising approach, directed specifically towards PWSA, seems to be the Multimodality Communication Program (Purdy & Dietz, 2010) but further study of the method is needed.

Verbal output is, not surprisingly, important to functional communication. In the absence of verbal output, executive function is important. However, these variables explain far from all the variation in functional communication. More research is needed to better understand what other factors might have an impact on communication in PWSA.

Testing the executive function in this population is a challenge. In this study, we used parts of the CLQT, which has a traditional pen and paper format. Perhaps there are other ways to measure executive function that might be more suitable for this population? Wall et al. (2017) suggested the Kettle test (Hartman-Maeir, Harel, & Katz, 2009), but also recognises that it has the disadvantage of being motorically demanding. Further investigation is needed to find optimal ways of assessing executive function in PWSA.
Conclusions

Our participants have clear impairments of executive functions, and there are moderate to strong correlations with all the linguistic measures. However, it is important to note that 15% of the participants perform at or above cut off for normal performance, and even within the nonverbal subgroup, the executive functions vary along the whole scale.

PWSA vary greatly when it comes to functional communication, and different ways of measuring functional communication give partly different results. There is a strong relationship between verbal output and functional communication in severe aphasia. Our results show that among people with no verbal output (either spoken or written), executive functions too are strongly related to functional communication.

Finally, language and non-linguistic cognition are intimately related and probably mutually dependent, both being crucial for the ability to communicate, and perhaps we will never be able to completely tease them apart to study one isolated from the other. However, it is clear that within the group of people with extremely limited or no verbal output, we can expect to find widely differing levels of LC, executive functioning, and functional communication. Hence, it is of great importance that PWSA, like any other stroke patients, are given a complete and proper evaluation of their strengths and challenges to provide individually adapted rehabilitation. Indeed, there can be many resources hidden behind the silence of severe aphasia. To support PWSA towards improved communication and social participation, a profound understanding of the factors involved in the communication is crucial.

Note

1. The parametric one sample t-test was used because the mean was the only value presented for the clinical sample in the test manual (Helm-Estabrooks, 2001).

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No potential conflict of interest was reported by the authors.

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References


Appendix 1. Assessment materials

Cognitive Linguistic Quick Test (CLQT)

CLQT is a test battery for the assessment of cognitive-linguistic functioning in adults with acquired neurological dysfunctioning that has been reported to have reasonable reliability and good validity (Helm-Estabrooks, 2001).

The criterion cut scores are based on an American sample, whereas the participants in this study are Swedish. Given the relative similarity of American and Swedish society (both countries can be regarded as Western individualistic cultures as opposed to Eastern collectivistic, which has been related to results on measures of executive functions (Kelkar, Hough, & Fang, 2013)) and the character of the tasks, this should pose no problem. However, as a further control of this issue, the scores were compared to the mean scores of the left-hemisphere-injured clinical sample included in the development of the CLQT (Helm-Estabrooks, 2001).

For the present study, four tasks from the test battery were used, which are described in greater detail below.

Symbol cancellation (CLQTsc)

The participant is given a paper filled with abstract, star-like symbols of five different designs and asked to mark all symbols of one special kind, which is demonstrated visually by the investigator. There is a time limit of 2 min. In scoring, attention is paid to the distribution of errors in the four quadrants of the visual field. The score is the number of correct cancelled symbols minus incorrect cancelled symbols, which gives a maximum score of 12.

Symbol trails (CLQTst)

The task is to draw lines between symbols in a defined order: in increasing size and alternating between circles and triangles. The concepts of increasing size and alternating between shapes are first demonstrated by the investigator and established separately in two practice tasks. The final test task has a time limit of 3 min. The numbers of correct lines are scored; the maximum score is 10.

Mazes (CLQTm)

The maze task consists of two mazes of increasing difficulty. The task is to draw a path through the maze from the starting point to the goal, which is indicated by an arrow and a pile of money, respectively, and pointed out by the investigator. The time limit for the first maze is 1 min and 2 min for the second maze. Each successfully completed maze generates a score of 4, with points subtracted each time a line goes a ½ inch into a wrong path. The maximum score is 8.

Design generation (CLQTdg)

The participant is presented with a number of squares with four dots in each and is instructed to draw as many unique designs as possible by connecting the dots in each square with four straight lines. Two example figures are completed by the investigator. The score is the number of designs generated minus perseverated, copied, and incorrect designs. The maximum score is 13.

Comprehensive Aphasia Test (CAT)

The CAT consists of three main parts: cognitive screen, language battery and disability questionnaire. For the present study, the language battery was used. Constituting the main part of the CAT, the language battery is a comprehensive assessment of spoken and written language comprehension and production. Good test–retest reliability and construct validity of the original English version has been reported (Swinburn et al., 2004).
The Swedish adaptation of the CAT used in this study was developed within a large project of adapting the test into several European languages (Fyndanis et al., 2017). When used for this study, a pilot testing of the Swedish version on a neurologically healthy group was completed (unpublished work) and the test was simultaneously undergoing validation on a large group of Swedish stroke survivors. The CAT was decided to be a better alternative for this study than previous existing Swedish aphasia assessments based on the high reliability and validity of the English version (Swinburn et al., 2004) and the high quality of the adaptation process.

**Scenario test (ST)**

The ST (van der Meulen et al., 2010) assesses functional communication through role-playing of situations. The PWA is presented with everyday scenarios (presented with pictures and described by the investigator) and then asked to convey a specific message within that situation; for example, to ask a waiter for the menu at a restaurant. Any mode of communication is accepted. If the message is communicated independently (with speech, gesture, writing, drawing, a communication aid, etc.), the participant achieves a full score. A reduction in score is made if some kind of prompting (which is given by the investigator in a specified way) is needed to switch communication mode, and as a final step, the investigator asks yes/no-questions. The ST has been found to have good reliability and validity based on a study of 122 PWA and 25 nonaphasic controls (van der Meulen et al., 2010).

The ST was translated to Swedish from the English version by the first author in collaboration with Joana Kristensson, PhD student at the Department of Neuroscience and Physiology, University of Gothenburg. A translation back to the original language of Dutch was made, which was controlled and approved by the original authors of the ST, who also provided training in administration and scoring.

**Communicative Effectiveness Index (CETI)**

The CETI uses 100 mm visual analogue scales where the partner (e.g., spouse, relative, neighbour, friend) rates the PWA’s performance in 16 different communication situations (e.g., “getting involved in group conversations that are about him/her”, “communicating his/her emotions”, “giving yes and no answers appropriately”). The score is the mean of the 16 items, and the maximum score is 100. A higher score indicates better communicative performance. Although the CETI is primarily developed to measure within-patient changes over time, it has been shown to have some validity also as an objective indicator of the severity of the communication problems of the PWA (Lomas et al., 1989). The CETI is judged to have good internal reliability and acceptable interrater reliability as well as good construct validity.