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Written text production and its relationship to writing processes and spelling ability in persons with post-stroke aphasia

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ABSTRACT

Background: Writing ability is of increasing importance in our computerised societies, yet research into functional text writing in persons with aphasia (PWA) remains scarce. Knowledge is limited of how different aspects of the writing process interact during writing. Spelling ability has commonly been investigated using dictation tests, but it is not known to what extent those results relate to spelling or editing in text writing.

Aims: To compare text writing in the production of narrative texts in persons with and without aphasia and to interrelate measures from the narrative output. Furthermore, to investigate how performance in dictation tasks related to spelling and editing in text.

Methods & Procedures: Fifteen participants with mild to moderate aphasia and 26 participants without aphasia in a reference group wrote two types of narratives in a keystroke-logging program and were tested with dictation tests. Writing process measures and characteristics from the texts were compared between groups. Writing process measures were interrelated for both groups. Spelling test results were correlated to spelling and editing in text for the group with aphasia.

Outcomes & Results: Significant differences between the two groups were found on all writing process measures; the PWA typed more slowly in the copytask, produced fewer words per minute and deleted a larger proportion of their texts while editing in two narrative tasks. There were also significant differences in text length and the amount of spelling errors in the picture-elicited narrative – but not in the free narrative. There were significant correlations between productivity and editing in both narrative tasks for the group with aphasia, but no such relation was found for the reference group, showing that for the PWA their productivity in text writing aligned with the amount of editing undertaken. A strong correlation between scores on the real-word dictation task and the amount of spelling errors in a picture-elicited text was found, but no correlation was found between scores on the real-word dictation task and spelling errors in the free narrative.

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Conclusion: All aspects of productivity in text writing were affected in this group of participants with mild to moderate aphasia. There was a relation between editing and production rate for the persons with aphasia, but not for the reference group. Scores on real-word spelling tests cannot predict spelling in free texts for PWA. Editing of writing is time-consuming and problematic for PWA and is worthy of specific focus within assessment and therapy for writing difficulty.

Introduction

Literacy skills are needed for many aspects of daily life in our modern societies (EU higher group, 2012). Until quite recently, literacy was often largely equated with the ability to read. However, as suggested by Brandt (2014), there seems to be an ongoing trend for reading to be replaced by writing as the main literacy activity: a shift from an era of *mass reading* to one of *mass writing*. For example, 90% of the Swedish population are Internet users (Davidsson & Thoresson, 2017) and/or communicate regularly using various written-language media on platforms such as smartphones, computers, and tablets. In such a society, questions about the consequences of acquiring a language disorder that influences reading and writing skills, such as aphasia, and about ways to facilitate writing in those people, take on added urgency. However, although numerous qualitative studies have found that persons with aphasia (PWA) view reading and writing as essential parts of the lives they led before being affected by aphasia (Kjellén, Laakso, & Henriksson, 2017; Knollman-Porter, Wallace, Hux, Brown, & Long, 2015; Lynch, Damica, Abendroth, & Nelson, 2013; & Parr, 1992), our knowledge about the nature and extent of writing impairments in this group is still limited.

Historically, writing research has focused on the *final text* (Mortensen, 2004). In recent decades, however, there has been a growing interest in the *production process* behind the text and in the writer's shifts of attention among the various higher- and lower-level processes involved in writing. Lower-level processes include spelling, typing, and lexical retrieval while higher-level ones include the generation of ideas, the evaluation, and revision of the text written so far and the development of overall text structure. In research on writing development, a model called the "simple view of writing" (Berninger et al., 2002b) has been used to explain how problems with lower-level processes may negatively affect higher-level processes. The model describes how two components (1) transcription (typing and spelling) and (2) executive functioning (planning, reviewing, editing, and evaluation of the text so far) enable the third component; (3) text generation. The model also stipulates that all processes are dependent on the limited space in the working memory. Lower-level processes are typically automatized to a large degree and therefore require less working memory space, allowing the writer to focus on higher-level processes. Hence, if lower-level processes (such as spelling, typing, or lexical retrieval) are de-automatised by aphasia, it would be reasonable to assume that this would have a negative indirect effect on higher-level writing processes.

Since aphasia may affect all aspects of language functioning, the ability to read and write is usually impaired. Many studies have focused on spelling ability, using single-word dictation tasks and the dual-route model (Ellis, 1982) to explain the results (for an overview, see Beeson & Rapcsak, 2015). As far back as 1931, Orton reported a discrepancy between children's performance in spelling tests and their spelling in text, suggesting the difference in processing demands between the two tasks as a reason for the discrepancy. However, for PWA, we have limited knowledge about the extent to which performance on single-word dictation tasks reflects spelling errors made during text writing.

There are a few studies of text writing, such as the production of narratives, in PWA (Thiel, Sage, & Conroy, 2015; Ulatowska, North, & Macaluso-Haynes, 1981; Vandenborre, Visch-Brink, van Dun, Verhoeven, & Mariën, 2018). One of the few published studies of narrative writing in persons with aphasia (Behrns, Ahlsén, & Wengelin, 2010) found that persons with post-stroke aphasia had difficulties at various linguistic levels: they wrote shorter texts and used less complex syntax than a reference group. They also made more word-level errors than the reference group, but in absolute numbers, they actually made rather few such errors and their overall text structure was well preserved. The same authors found in a different study (Behrns, Ahlsén, & Wengelin, 2008) that the production rate (words in the final text divided by the time on task) was three times lower in the same group with aphasia than in the reference group. This lower production rate was attributed to lexical-retrieval difficulties, spelling difficulties and a time-consuming editing process. In the latter study, those results were obtained by investigating the writing process during a narrative-writing task using a keystroke-logging tool.

There are many direct and indirect methods that can be used to investigate the writing process, including think-aloud protocols, video recordings, retrospective protocols, and text analysis (Janssen, van Waes, & van den Bergh, 1996). However, many of them are unsuitable for research involving persons with aphasia, since their writing process is easily disturbed and their texts tend to be short (Behrns et al., 2010). In recent years it has become possible to use an unintrusive method to record the writing process by using keystroke-logging software. This enables observation of the writing process as it unfolds and analysis of temporal patterns, editing, and other aspects of the process (Leijten & Van Waes, 2013). Keystroke logging was used in the present study.

We still have limited knowledge of how having aphasia affects text writing and of what aspects of text writing for PWA differ from text writing for a matched reference group. There is also a need for knowledge into how different aspects of the writing process interact, for example, whether the rate of text production is related to extensive editing for PWA, as suggested in Behrns, Ahlsén and Wengelin (2008) and if there is a relation between typing speed and production rate, and whether similar relations can be found in a reference group. It is known that spelling difficulty is common for PWA thus requiring additional cognitive resources while writing. Furthermore, it is known that spelling difficulty for PWA not only presents as errors in the final text but also as editing difficulties during text production. But as previously mentioned, we do not know to what extent results of spelling in a dictation task relate to spelling in text writing and editing for PWA and whether that relation is dependent on the type of writing task. For this reason, the present study used tests of spelling along with text writing tasks.

Aim

The aim of this study was to examine and compare text writing in the production of narrative texts in persons with and without aphasia and to interrelate measures from the narrative output for both groups. Measures of writing and writing processes are also related to scores on tests of spelling for the persons with aphasia.

Research questions:

- (1) How do measures of the writing process (typing speed, production rate, and editing) and text characteristics (spelling and text length) distinguish the written output of people with and without aphasia in narrative writing?
- (2) What are the relations between typing speed, production rate and editing for both groups?
- (3) What are the relations between spelling in dictation tests, spelling in text, and editing for the participants with aphasia?

Methods

To answer the first research question, comparisons were made on group level between a group of participants with aphasia (“A group”) and a reference group of persons without aphasia (“R group”). The second research question will be answered using bivariate correlations to investigate relationships between writing process measures for both groups. And finally, to answer the third research question, bivariate correlations were used to investigate, for the A group, the relationships between scores on dictation tests, writing-process measures, and spelling in the texts.

Ethical considerations

The present study was approved by the Regional Ethical Review Board of Gothenburg, Sweden (Ref. No. 525–14). Participants were given both spoken and written information about the study to facilitate and ensure comprehension. They all gave their written consent to participate. Before the study began, each participant’s name was replaced with a code which was subsequently used in the handling of the results.

Participants

Group with aphasia

The participants with aphasia were contacted through local aphasia associations and via speech-language pathologists in the western part of Sweden. Background data about their onset of stroke and their language disorder were collected from their medical records.

The criteria for inclusion in the study were: (1) aphasia due to stroke, (2) a score above 2.5 on the “A-ning” (Lindström & Werner, 1995, see under “Tests” below) subtests of writing (corresponding with the ability to use more than words in isolation in written production) or auditory comprehension (corresponding with the ability to understand

spoken sentences, thus understanding verbal instructions), (3) ability to use a computer keyboard, (4) a minimum of 6 months since the onset of aphasia, (5) age over 18 years, and (6) Swedish as one of their first languages. Exclusion criteria were (1) developmental reading and writing difficulties or other learning impairment existing prior to the stroke and (2) a hearing or visual impairment which could not be compensated for.

A total of 18 participants meeting the inclusion criteria were recruited to the study. The inclusion criteria regarding performance in subtests of writing and auditory comprehension resulted in a group of participants with mild to moderate aphasia. Three of them were excluded from the analysis: one owing to technical problems, one owing to failure to complete the tests because of fatigue and one owing to revealing developmental reading and writing difficulties after the tests. Hence, the group with aphasia (A group) consisted of 15 participants, who are described in Table 1.

Reference group

A convenience sample of 26 adults was recruited through community organisations. The inclusion criteria were (1) age over 18 years and (2) having Swedish as one of their first languages. Exclusion criteria were (1) neurological disease or disorder, (2) developmental reading and writing difficulties or other learning impairment and (3) hearing or visual impairment which could not be compensated for. The data from the R group were collected by two final-year speech-language pathology students, a research assistant, and the first author. The R group consisted of 26 adults without any known neurological disease.

The groups were matched for age and years of formal education. No statistically significant differences were found between the two groups in terms of age (A group: $M = 69.13$, R group: $M = 67.96$; $t = 0.610$, $p = 0.547$) or years of formal education (A group: $M = 15.13$, R group: $M = 15.65$; $t = -.381$, $p = 0.707$). There were 42% women and 57% men in the R group (compared with 27% women and 73% men in the A group).

Table 1. The participants with post-stroke aphasia (A group).

Code	Sex	Age	Years of formal education	Time since onset of aphasia	Overall A-ning score	Type of aphasia
A1	M	71	18	4 yrs.	3.9	Non-fluent
A2	M	61	11	14 yrs.	3.9	Non-fluent
A3	M	70	20	9 yrs.	4.3	Non-fluent
A4	M	58	18	14 yrs.	3.5	Non-fluent
A5	M	72	17	8 yrs.	4.2	Non-fluent
A6	M	63	25	10 mths.	4.5	Non-fluent
A7	M	79	20	7 mths.	4.6	Mixed/fluent
A8	M	70	17	6 yrs.	4.4	Mixed
A9	F	72	10	9 yrs.	3.8	Mixed
A10	M	71	16	7 yrs.	4.1	Mixed
A11	F	72	9	4 yrs.	4.6	Non-fluent
A12	M	79	13	8 yrs.	4.4	Non-fluent
A13	F	65	9	2 yrs.	2.8	Fluent
A14	F	67	12	29 yrs.	4.4	Non-fluent
A15	M	67	12	5 yrs.	3.3	Non-fluent
N = 15		M: 11, F: 4	M = 69.13	M = 15.13		

The A-ning overall score ranges from 0 to 5; 5 means no aphasia (Lindström & Werner, 1995).

Keystroke logging

Keystroke-logging software is a computer tool designed to record all keyboard and mouse activity during a writing process (Strömqvist, Holmqvist, Johansson, Karlsson, & Wengelin, 2006; Van Waes, Leijten, Wengelin, & Lindgren, 2012; Van Waes, Leijten, Lindgren, & Wengelin, 2016) in real time. This makes it possible to analyse what the writer has done while producing the text and to observe the writing process as it unfolds (Wengelin et al., 2009). The analysis of fluency, pauses and revisions yields temporal patterns which provide information about the cognitive effort required for different parts of the writing process. The keystroke-logging tool used in the present study was New ScriptLog (Wengelin, Frid, Johansson, & Johansson, 2019). Figure 1 shows a “linear file” (LIN file) representing the writing process of a participant with aphasia. Alphanumerical characters are in red. The numbers within brackets represent pauses (longer than 2 s) in milliseconds (ms) and the letters within brackets represent the pressing of non-alphanumerical keys. The LIN file should be read as follows: First, there was a pause lasting for 10295 ms (just over 10 s). Then, the writer wrote the word *Jag* (“I”) and paused for 20925 ms before writing the letters *gl*. Then, the writer immediately deleted the *l* using the backspace (BACK) key. And so on ...

Text-production tasks

Three text-production tasks were administered – a copy task, a picture-elicited narrative task and a free narrative task.

The copy task was used to measure participants’ basic typing skills. Such tasks are deemed appropriate for this purpose because they minimise the cognitive effort required for language functions such as lexical retrieval, planning, spelling, translation, and memory functions, hence providing a basic measure of the participant’s typing speed

```
{10295}Jag-{20925}gl[BACK]{3345}{13848}[LEFT][LEFT]{5225}gö{8718}[RIGHT]
[RIGHT][BACK][BACK][BACK]g[BACK]{2501}j{2598}o{7110}r{12051}[LEFT][LEFT][LEFT][LEFT]{132
38}[RETURN][BACK][RETURN][BACK][BACK]
·[RIGHT][RIGHT][RIGHT][RIGHT]{2664}d{2081}r[BACK]{2917}e{7983}
[LEFT][LEFT][LEFT][LEFT][LEFT][LEFT]{7139}s{3243}[BACK]{2466}[RIGHT][RIGHT][RIGHT]
[RIGHT][RIGHT]·{5680}n{8941}ä{2194}[BACK]åggö[BACK][BACK]u[BACK]{5814}o{3366}n
·{23324}g{3447}a{2885}d·{12726}n{3080}r[BACK]{3253}är·{14483}
ko{5651}[BACK][BACK]{2439}jag·{21340}ko{2183}m·{3885}till·{7304}a
bo[BACK]{2416}r[BACK]{8578}e[BACK]re[BACK][BACK]{11110}[BACK]rba[BACK]e{4591}t
{6923}e{5633}n[BACK]{29400} n[BACK]t{4001}·{99020} N[BACK]{55869}
[RETURN]{21348}A{3511}t{2467}[BACK]r{11109}b{3131}e{2673}t{22373}
·ka{10354}me[BACK]{15811}o[BACK][LEFT][LEFT][LEFT][LEFT]{7632}s{5244}
[RIGHT][RIGHT][RIGHT][RIGHT]{6297}n[BACK]{2520}k[BACK]{19900}p[BACK]{8220}[LEFT][LEFT]
{8955}[RIGHT][RIGHT]{47450} [RETURN]{27949}
[UP][UP][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][
RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIG
HT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIG
HT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT][RIGHT]
```

Figure 1. The beginning of the linear file of one participant’s free narrative.

(Grabowski, 2008). Concretely, the participants were instructed to write a well-known Swedish proverb, *Bättre sent än aldrig* (“Better late than never”), between five and twelve times. They were instructed orally but also had the proverb displayed on their computer screen throughout the task, meaning that they wrote from memory but were able to look at the model sentence if and when they needed additional support.

The picture-elicited task was intended to elicit narratives with a story-telling structure and to generate longer texts. This task was based on the title page and six of the pictures in the wordless children’s picture book *Frog, where are you?* (Mayer, 1969). The participants were instructed to write a story to the pictures in the short version of the book used. The pictures, including the title page, were shown on the screen one by one. The participants were able to change pictures themselves, but the participants with aphasia tended to ask the test leader to change pictures for them.

The free narrative (on a set theme) was intended to resemble an everyday writing event more closely and so have ecological validity. The theme was “Last time I made someone happy”. The theme was shown on the screen throughout the task for support. There was no time constraint in any of the writing tasks, since the intent was to investigate how the participants would perform on a writing task in daily life. The participants were encouraged to write until they were satisfied with the narrative.

Writing variables analysed from text-production tasks

A number of writing variables were used. They are described in Table 2. Note the distinction between process measures, which relate to the text as it emerges, and text characteristics, which relate to the final text produced.

Tests

Aphasia severity was measured using “A-ning” (Lindström & Werner, 1995). This is a Swedish neuro-linguistic aphasia examination tool consisting of a standardised screening-test battery which is used to measure the type and severity of a language impairment. A standardized instrument, A-ning is the test most commonly used for diagnosing aphasia in Sweden. The test battery includes a number of subtests measuring different aspects of language function. The overall score (range: 1–5) on A-ning was used to describe the participants with aphasia in Table 1, while subtest scores were used as inclusion criteria.

Table 2. Description of the writing measures used.

Measure	Operationalised as
Process measures	
Typing speed	Median inter-key interval between characters within a word (expressed in seconds) in the copy task.
Production rate	The total number of words in the final text divided by the total time on task in minutes (expressed as words per minute) in the narratives.
Proportion of un-edited text	The total number of “tokens” (alphanumerical characters, punctuation, spaces and any other visible results of key presses) in the final text divided by the total number of instances of the pressing of token keys (expressed as a percentage) in the narratives.
Text characteristics	
Text length	The total number of words (strings of characters between spaces or delimiters) in the final text (expressed as a number) in the narratives.
Spelling errors in text	The number of words in the final text containing one or more spelling errors divided by the total number of words in the final text (expressed as a percentage) in the narratives.

Spelling in test was measured using two dictation tasks. Although originally developed to model reading of isolated words, “the dual route model” (Ellis, 1982; Hatfield, 1989) is frequently used to explain acquired spelling and writing difficulties. The dual route model suggests two basic independent routes for processing written words: the lexical route and the sub-lexical route. For unimpaired readers and writers the routes are both accessible, but for persons with aphasia one route might be selectively impaired (Ellis, 1982; Hatfield, 1989). The rationale behind using the two dictation tasks was to obtain a measure of both lexical and sub-lexical (phoneme-grapheme-conversion) spelling ability.

The first was a single-word dictation task from the LS test battery (Johansson, 2004) which was originally developed for 7th-year students and contains 50 words. One word was excluded from the analysis since it prompted the writing of digits instead of letters. The second dictation task measured spelling of non-words using 18 non-words/pseudo words from a longer decoding task in the LS test battery (Johansson, 2004). The words used have plausible Swedish phoneme combinations but no lexical meaning. Each non-word was read aloud by the author, and the participants were instructed to write the word as they heard it. There was no time limit to the task and no limit to the number of repetitions that the participants could obtain, but the author always read the word in its entirety. Both dictation tasks were performed in ScriptLog, but the writing processes recorded will not be analysed for the purposes of this article, since it is beyond the scope of this study. Instead, the final written words were used for the analysis and scoring of spelling ability in test.

Procedures

Data collection for the group with aphasia took place at the Speech-Language Pathology Unit, at the local aphasia association or in the participant’s home. The participants with aphasia attended two test sessions on different days. During the first session, the participants performed two spoken narrative tasks before performing the writing tasks. The spoken narratives were video-recorded but are not analysed in the present study. The writing tasks began with the copy task, followed by the non-word dictation task and the two written narratives. To reduce the effect of task order, the order of the two narrative tasks was randomised. The first test session was the same for both groups. During the second session, the participants with aphasia performed the real-word dictation task. It was not deemed necessary to have the reference group perform it since there are norms in the test manual which can be used for comparison (Johansson, 2004).

Statistical analysis

All statistical analyses are based on the results from 15 participants in the A group and 26 participants in the R group. However, there was missing data from one participant regarding the process measures in the free narrative, due to technical error. Because of the relatively small sample size and the variation found in the data, non-parametric statistical methods were used; the results should be interpreted with caution. Comparisons of writing measures between the A group and the R group were performed using the Mann Whitney U test. The level of statistical significance was set to $p < 0.05$. The relationships between writing measures for both groups and for writing measures and

scores from spelling tests for the A group were investigated by means of bipartial correlations using Spearman's rho. Statistically significant correlations will be interpreted for correlation strength in accordance with the guidelines of Martella, Nelson, Morgan, and Marchand-Martella (2013): 0.21–0.40 = weak correlation, 0.41–0.60 = moderate correlation, 0.61–0.80 = strong correlation, and 0.81–1 = very strong correlation. Raw scores were used in the analysis of results from dictation tests. All statistical analyses were performed using the IBM SPSS Statistics Data Editor.

Results

Before presenting the results of the study, an example of narratives written by a person with aphasia from the A-group is presented, see Figure 2.

The example illustrates the text production in the two different narrative tasks.

The results from the comparisons of writing measures at group level between the group with aphasia (A group) and the reference group (R group) will be presented first. Then, analyses of correlations between measures of the writing process for both groups will be presented. After that, the A groups' results on the tests of spelling will be accounted for. Finally, the analyses of correlations between spelling in test, spelling in text and editing for the A group will then be presented.

Differences between the groups on writing measures from text production

The various measures derived from the text writing tasks were compared between the A group and the R group. Because those measures were not normally distributed, the comparisons were performed using the Mann–Whitney U test for independent samples. The results are shown in Table 3.

Picture-elicited narrative, titled "Frog, where are you?"	
<i>Original text in Swedish</i>	<i>English translation</i>
Grodan, var är du?	<i>Frog, where are you?</i>
Kille och hund sova. I natt och mån*.	<i>Boy and dog sleep. To night and mån*</i>
Grodan <u>glasflask</u>	<i>The frog bottl</i>
Kille och hund på morgon.	<i>Boy and frog in the morning.</i>
Kille och hund hopp. Bizzzzz**	<i>Boy and frog jump. Bizzzzz**</i>
Kille och hund träd och grodan enda sidan.	<i>Boy and dog trees and frog only side.</i>
Grodan <u>familje</u> han och hon åttor smågrodan.	<i>Frog famil he and she eights the little frog.</i>
Kille och hund hejdå, <u>familje</u> grodan.	<i>Boy and dog good bye, famil the frog.</i>
Free narrative, Themed "Last time I made someone happy"	
Senast jag gjorde någon glad.	<i>Last time I made someone happy.</i>
Mamma och pappa fotboll <u>översk</u>	<i>Mom and dad football surpri</i>

Figure 2. Examples of narratives written by a participant with aphasia. Note. The titles of the narratives were given. Text translated to English in italics. Misspelled words in Swedish (underlined) translated to misspelled English. * Mån might be an attempt to spell måne (Eng. moon) but since *mån* is a word in Swedish it was not regarded as a misspelled word. The word was left un-translated since there was no corresponding English word. **Onomatopoetic words were regarded as correct, if the phonology was acceptable (in this case describing the buzzing of bees).

Table 3. Group comparisons of writing measures in the A group and the R group.

Writing measure	A group (N = 15)		R group (N = 26)		Significance
	M (SD)	Mdn (Min–Max)	M (SD)	Mdn (Min–Max)	
<i>Process measures</i>					
Typing speed in CT (sec)	.84 (.42)	.73 (.34–1.85)	.30 (.13)	.28 (.14–.74)	U = 19.00 p < .001*
Production rate in PE (words/minute)	3.86 (2.24)	3.45 (1.25–8.52)	11.86 (6.51)	10.10 (2.57–28.49)	U = 30.00 p < .001*
Production rate in FN (words/minute)	3.84 (3.02)	3.33 (.77–12.09)	19.45 (7.74)	20.37 (7.16–36.48)	U = 6.00 p < .001*
Proportion of un-edited text in PE (%)	86.34 (10.48)	86.87 (67.46–100)	95.12 (3.65)	96.62 (85.36–99.22)	U = 88.00 p = .004*
Proportion of un-edited text in FN (%)	84.13 (13.01)	88.13 (60.99–99.13)	94.60 (6.23)	96.39 (70.09–100)	U = 80.00 p = .004*
<i>Text characteristics</i>					
Text length in PE (words)	67.27 (23.31)	70.00 (32–110)	184.65 (79.24)	171 (60–369)	U = 19.00 p < .001*
Text length in FN (words)	25.50 (15.25)	25.50 (8–54)	112.19 (48.46)	102.50 (20–242)	U = 9.50 p < .001*
Spelling errors in text in PE (%)	7.16 (9.21)	4.17 (0–34.38)	1.07 (1.52)	.64 (.00–5.59)	U = 102.00 p = .010*
Spelling errors in text in FN (%)	6.29 (8.71)	2.64 (0–25.00)	.71 (1.04)	.00 (.00–3.96)	U = 146.00 p = .158

* p < 0.05. Abbreviations: PE = picture-elicited narrative, FN = free narrative.

As could be expected, there were statistically significant differences between the two groups on all process measures. In other words, compared with the R group, the members of the A group (on average) typed more slowly in the copy task, produced fewer words per minute and deleted a larger proportion of their texts while editing in both narrative tasks. There were statistically significant differences in the amount of text produced and in the proportion of word-level errors in the picture-elicited narrative – but not in the proportion of word-level errors in the free narrative.

Correlation analyses of relations between writing process measures for both groups

Writing process measures were analysed also using Spearman's rho correlation. Results for the A group are presented in Table 4, below.

A significant negative correlation was found between typing speed and production rate in the free narrative, meaning that a lower median time between keystrokes (which equals a higher typing speed) was related to higher production rate. There were also

Table 4. Correlations between writing process measures, A group.

Variables	Typing speed	Production rate in PE	Production rate in FN	Proportion of un-edited text in PE (%)	Proportion of un-edited text in FN (%)
Typing speed	1	-.459	-.604*	.000	-.213
Production rate in PE		1	.801**	.561*	.344
Production rate in FN			1	.393	.569*
Proportion of un-edited text in PE (%)				1	.613*
Proportion of un-edited text in FN (%)					1

Correlation analyses performed using Spearman's rho. * p < 0.05, ** p < 0.01. Abbreviations: PE = picture-elicited narrative, FN = free narrative.

significant correlations between the production rate and the proportion of un-edited text for both narrative writing task, which shows that a higher proportion of editing related to a lower production rate. Significant correlations were found between the same writing process measures across the two narrative writing tasks, which would be expected.

Correlations performed for the A group were also analysed for the R group and results are presented in Table 5, below.

Significant correlations were found between typing speed and production rate in both narrative writing tasks for the R group; however, the relation was negative in the free narrative and positive in the picture-elicited. This means that in the free narrative, that there was a relation between high typing speed and a higher production rate, whereas the opposite was true for the picture-elicited. As for the A group, there were significant correlations between the same writing process measure across narrative writing tasks. There was also a correlation between typing speed and editing in the free narrative, suggesting a relation between how fast the participants typed and how much they edited their texts.

Correlation analyses of spelling in test, spelling in text and editing for the A group

Table 6 shows mean scores on the spelling tests (dictation and non-word dictation). For the real-word dictation test, the A group’s score is in fact given along with a norm value taken from the test manual, but for the non-word dictation, actual mean scores of both groups are presented.

The correlations between spelling in test expressed as scores on the two dictation tests, spelling in text (expressed as the proportion of word-level spelling errors in the final text) and editing (expressed as proportion of un-edited text) were analysed, using Spearman’s rho; the results are presented in Table 7.

The analysis showed that there was a moderate correlation between scores on the two dictation tasks, showing that there is a relation between sub-lexical and lexical spelling

Table 5. Correlations between writing process measures, R group.

Variables	Typing speed	Production rate in PE	Production rate in FN	Proportion of un-edited text in PE (%)	Proportion of un-edited text in FN (%)
Typing speed	1	,669**	-,828**	,119	,416*
Production rate in PE		1	-,553**	-,342	,099
Production rate in FN			1	,109	-,104
Proportion of un-edited text in PE (%)				1	,601*
Proportion of un-edited text in FN (%)					1

Correlation analyses performed using Spearman’s rho. * p < 0.05, ** p < 0.01. Abbreviations: PE = picture-elicited narrative, FN = free narrative.

Table 6. Scores on tests of spelling.

Test scores	A group	R group	Norm value	Max score
	M	M	M	
Dictation	22.67	-	38.2 ^A	49
Non-word dictation	5.2	14.15	-	18

^A= Norm value for upper-secondary-school students, taken from the test manual. Scores are counted as the number of correct words. Abbreviation: M = mean.

Table 7. Correlations between scores on tests of spelling, spelling errors in text and proportion of un-edited text, A group.

Variables	Spelling (word dictation)	Spelling (non-word dictation)	Spelling errors in text in PE (%)	Spelling errors in text in FN (%)	Proportion of un-edited text in PE (%)	Proportion of un-edited text in FN (%)
Spelling (word dictation)	1					
Spelling (non-word dictation)		.565*				
Spelling errors in text in PE (%)			1			
Spelling errors in text in FN (%)				1		
Proportion of un-edited text in PE (%)					1	
Proportion of un-edited text in FN (%)						1

Correlation analyses performed using Spearman's rho. * $p < 0.05$. Abbreviations: PE = picture-elicited narrative, FN = free narrative.

ability in the dictation tests. There was also a strong correlation between scores on the (real-word) dictation task and the proportion of spelling errors in the picture-elicited text, meaning that the participants who obtained high scores in the word dictation task had a lower proportion of spelling errors in the picture-elicited text. However, there was no correlation between scores on the real-word dictation task and the proportion of spelling errors in the free narrative, which suggests that spelling in a word-dictation test does not transfer to spelling in free text. The proportion of un-edited text did not correlate significantly to spelling in test or spelling errors in text for any of the text writing tasks, meaning that the amount of editing undertaken by the participants with aphasia did not relate to spelling ability as measured in tests or in texts.

Discussion

The results showed that there were statistically significant differences between the two groups on all measures of the writing process, meaning that the group with aphasia are far less fluent writers than the reference group. They typed more slowly in the copy task, they had a lower production rate and wrote shorter narratives. Although these results were expected and are in line with those of Behrns et al. (2008) and Vandenborre et al. (2018), they shed some more light on the full extent of the disability. In fact, the A group's production rate was almost three times lower than that of the R group in the picture-elicited task, and the difference was even greater in the free-narrative task. The images used in the picture-elicited narrative seemed to function as narrative support for the participants with aphasia, enabling them to write longer texts than they did in the free-narrative task. It is possible that the free narrative task placed greater demands not only on high-level processes such as text planning, idea generation and text structure, but possibly also on lexical retrieval. It should be noted that an impaired lexical-retrieval function is one of the integral and most persisting symptoms of aphasia in speech (Goodglass, 1997) and would be expected to be mirrored in written production (Kay, Lesser, & Coltheart, 1992). The inference that the pictures functioned as support for the A group is also supported by the fact that for the R group, their production rate (in mean and median values) was almost halved when writing the picture-elicited narrative, but for the A group, their production rate remained somewhat stable across narrative tasks.

Comparisons between the A group and the R group showed that the A group edited their texts more than the R group did; a larger proportion of keystrokes were deleted during the composition of the text. This finding differs from those of Behrns et al. (2008), where no such differences at group level could be seen. There were also correlations between the production rate and the proportion of unedited text for both narrative tasks, meaning that there is a clear link between the amount of editing that participants undertake and their overall productivity, where a higher amount of editing related to a lower production rate. The R group also edited their texts (as do all writers), but the editing did not relate to their production rate. So while editing in the R group clearly took some time investment, this was negligible and did not significantly detract from the overall time efficiency of their writing. Behrns et al. (2008) showed that editing is an extremely time-consuming activity for writers with aphasia and that they most often edit at word level. The trial-and-error editing strategy used by the writers with aphasia was found to be most time-consuming and would result in a large proportion of edited text.

Further analysis would be required to determine the nature of the editing operations made by the participants in this study. There were no significant correlations between editing and spelling in text for the participants with aphasia in either task meaning that there is no relation between the amount of editing undertaken and the editing outcome (correct or un-correct spelling) in text. Hence, the participants who had few errors in their final texts did not edit less than the others, they edited more successfully. Results could be interpreted in relation to the model “the simple view of writing” (Berninger et al., 2002b), where participants in the reference group appeared to shift their attention between writing processes without affecting the text generation, whereas for participants with aphasia, text generation was affected, which was evident from lower production rate and shorter texts. As has been previously reported by Behrns et al. (2008), the participants with aphasia were preoccupied with editing on word level due to spelling and editing difficulty.

The group comparisons showed that the A group had a slower basic typing speed in the copy task than the R group did. A few of the participants in the A group suffered from motor or sensory disability of their right hand – as do many stroke survivors with aphasia. The severity of this disability ranged from no disability or a light numbness to paralysis or disabling spasticity. However, the difference in typing speed between the A group and the R group cannot be attributed solely to motor aspects. A qualitative review of the final texts from the copy task revealed a high prevalence of word-level errors, missing words from the proverb and perseverations of words or parts of words in the A group’s output, suggesting that linguistic issues remain even when the task involves copying an over-learned sentence. The copy task is generally regarded as a task imposing low cognitive demands (Grabowski, 2008), but it was in fact quite taxing for the participants with aphasia. This is a further illustration of the extent of de-automatisation caused by aphasia. This de-automatisation would then impact the overall text generation negatively by imposing extra weight on the verbal working memory (Berninger et al., 2002b) since the writer would depend on the smooth and fluent transitions between more automatized lower-level processes and higher level processes. For the R group, a faster typing speed was related to a higher production rate in the free narratives, which means that the R group writes with more fluency and speed than the A group, and that their lower proportion of editing does not seem to slow their production rate down. However, a surprising result was that there was a significant correlation between a higher typing speed and a lower production rate in the picture-elicited task for the R group. A speculation could be that the faster typists were proportionally more hindered by the pictures than the slower typists. Furthermore, the significant correlation between typing speed and editing in the free narrative suggests that slower (maybe also more inexperienced) typists tend to edit more of their text.

Performance on dictation tests and word-level errors in texts

The results showed that there was no correlation between scores from spelling in test of the participants with aphasia (as measured in the dictation tasks) and the proportion of spelling errors in the final texts in the free narratives, meaning that there was no relationship between how well the participants were able to spell in a dictation task and how well they spelled in a narrative-writing task. This is an important finding, since performance in

dictation tasks is commonly equated to spelling ability (and in some cases even writing ability) in persons with aphasia. It further underscores the importance of looking beyond single-word dictation tasks when examining the writing ability of persons with aphasia, as has been suggested by Thiel et al. (2015) and Thiel, Sage, and Conroy (2017). The results also point to a fact which has long been known by clinicians who work with persons with aphasia: tests scores measuring isolated abilities do not necessarily correspond with functional ability in a more complex task. Text writing is a cognitively complex task requiring both linguistic abilities as well as other cognitive abilities such as working memory and executive functions. Moreover, this finding is well in line with those from research on adults with developmental dyslexia (Wengelin, 2002). It seems that, whenever possible, persons with both acquired and developmental writing difficulties tend to avoid words whose spelling they are unsure of. This interpretation is also supported by the fact that, in the present study, there was no statistically significant difference between the groups with regard to the proportion of word-level errors in the free narrative, but there was such a difference for the picture-elicited narrative (where the pictures will have reduced the opportunities to avoid certain hard-to-spell words). However, the variation in the proportion of word-level errors in texts was substantial for the A group (from 0% to 34% in the picture-elicited narrative and 0% to 25% in the free narrative) and even though the use of non-parametrical statistical tests, extreme values could still interfere with the results of the comparisons.

Studies of lexical aspects of the spelling errors made by persons with aphasia have shown that words which are infrequent, long and abstract, and where that to which the word refers is difficult to imagine, are more often misspelled than those with the opposite characteristics (Beeson & Hillis, 2001; Behrns et al., 2010; Whitworth, Webster, & Howard, 2006). If the participants with aphasia tended to avoid words belonging to the first category above and to replace them with words belonging to the second category, the result might well be a vaguer and less informative text, as has in fact been reported by Behrns et al. (2010). However, no such analysis was performed of the texts produced in the present study. Lexical features, cohesion, coherence, and overall text quality might be suggested for focus in future research on text characteristics for persons with aphasia.

It is worth noting that there was a strong correlation between performance on the dictation tasks and the number of spelling errors in the picture-elicited narrative task, where – as mentioned above – the content and hence the vocabulary were more controlled than in the free-narrative task. Hence, caution must be exercised in the choice of the type of writing task used to assess writing accuracy and writing ability in persons with aphasia.

Limitations

An overall limitation in the study is the relatively small number of participants in the A group, all having mild to moderate aphasia. The group is a result of the study's inclusion and exclusion criteria, where the participants were required to be able to write a connected text and to comprehend connected speech. A larger number of participants would have been desirable both to enable other statistical methods, such as the use of regression models, but also in relation to the distribution of type of aphasia. In the current study, only one participant was regarded as having fluent aphasia and four had mixed

fluent and non-fluent aphasia profiles. A larger representation of participants with fluent aphasia could have contributed to the analysis and enabled analysis of results from writing in relation to type of aphasia.

Time since onset of aphasia might have impact on the results and the variation is large in the study group. However, since writing difficulties is one of the most persisting symptoms of aphasia, no upper limit for time since onset of aphasia was set in the current study.

An added difficulty was that the A group had large variations on all writing measures and dictation test scores, which adds statistical uncertainty in comparisons and correlations.

The free narrative was on a set theme to make the texts more comparable. However, there are always individual differences in how the person approach such a free task, as was evident from texts written by the A group as well as in the R group.

Conclusion and implications

When writing ability is proven to be of increasing importance for participation in daily life, a more functional approach to writing difficulties associated with aphasia is warranted in research and in aphasia treatment (Thiel et al., 2015; Thiel et al., 2017). Furthermore, there is a need for examining both written output as well as what cannot be seen in the output, which is the writing processes, the work behind the final texts. This is now possible due to technological tools, such as keystroke logging. Comparisons between the group with aphasia and the reference group showed that all aspects of productivity in text writing were affected for a group with mild to moderate aphasia. In this study, more text editing was related to a lower productivity but not to more spelling errors in the final text. Hence, treatment for writing difficulty could entail training of efficient editing strategies to elicit text generation.

Used to assess spelling ability, dictation tests can be easily administered and corrected, but scores cannot predict spelling in free texts and should not be used alone to assess severity of writing difficulty. This study shows that spelling in a word-dictation task cannot be expected to predict spelling in a free-narrative task. The paradigm shift to a more functional approach, which has to some extent taken place in the research and treatment for spoken word difficulties, is yet to come in aphasiology in regards to writing.

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