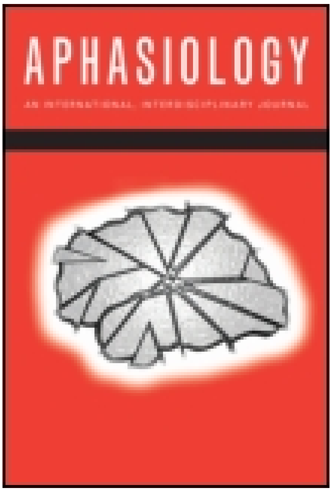

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Sentence comprehension disorders in aphasia: The concept of chance performance revisited

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Sentence comprehension disorders in aphasia: The concept of chance performance revisited

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Background: In behavioural tests of sentence comprehension in aphasia, correct and incorrect responses are often randomly distributed. Such a pattern of chance performance is a typical trait of Broca's aphasia, but can be found in other aphasic syndromes as well. Many researchers have argued that chance behaviour is the result of a guessing strategy, which is adopted in the face of a syntactic breakdown in sentence processing.
Aims: Capitalising on new evidence from recent studies investigating online sentence comprehension in aphasia using the *visual world paradigm*, the aim of this paper is to review the concept of chance performance as a reflection of a syntactic impairment in sentence processing and to re-examine the conventional interpretation of chance performance as a guessing behaviour.
Main Contribution: Based on a review of recent evidence from visual world paradigm studies, we argue that the assumption of chance performance equalling guessing is not necessarily compatible with actual real-time parsing procedures in people with aphasia. We propose a reinterpretation of the concept of chance performance by assuming that there are two distinct processing mechanisms underlying sentence comprehension in aphasia. Correct responses are always the result of normal-like parsing mechanisms, even in those cases where the overall performance pattern is at chance. Incorrect responses, on the other hand, are the result of intermittent deficiencies of the parser. Hence the random guessing behaviour that persons with aphasia often display does not necessarily reflect a syntactic breakdown in sentence comprehension and a random selection between alternatives. Instead it should be regarded as a result of temporal deficient parsing procedures in otherwise normal-like comprehension routines.
Conclusion: Our conclusion is that the consideration of behavioural offline data alone may not be sufficient to interpret a performance in language tests and subsequently draw theoretical conclusions about language impairments. Rather it is important to call on additional data from online studies that look at language processing in real time in order to gain a comprehensive picture about syntactic comprehension abilities of people with aphasia and possible underlying deficits.

Keywords: Sentence comprehension in aphasia; Chance performance; Visual world paradigm; Eye tracking; Online sentence processing.

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Individuals with aphasia often experience difficulties in comprehending sentences. Comprehension disorders at the sentence level are determined by two factors: thematic reversibility and word order. An event referred to in a declarative sentence is called *reversible* when all the participants in this event are animate and can equally be assigned the thematic roles of AGENT or THEME (e.g., *The horse kicks the cow*) without rendering the event implausible. In contrast, an event is called *irreversible* when one participant is inanimate (e.g., *The horse kicks the fence*) and, therefore, the distribution of thematic roles is fixed. In contrast to irreversible sentences, reversible sentences are much harder to understand by people with Broca's aphasia and other syndromes. Apart from reversibility as a necessary condition, the factor word order plays a crucial role for the observed phenomenon: reversible sentences with a non-canonical word order in which the object appears before the subject are more affected than reversible canonical sentences (Burchert, De Bleser, & Sonntag, 2003; Caramazza & Zurif, 1976; Grodzinsky, 1995a, 1995b; Mitchum & Berndt, 2008).

In order to assess sentence comprehension in individuals with aphasia, a majority of researchers have used test paradigms such as the Sentence–Picture Matching task (SPM henceforth). In this kind of task participants see pictures representing actions, and they are asked to point to one of them following the auditory or written presentation of a reversible sentence in either a canonical or a non-canonical word order. A typical SPM task consists of two pictures displaying the action mentioned in the sentence with either the correct distribution of thematic roles of the actors in the event (= target picture) or the reversed distribution (= incorrect/foil picture). In other studies additional foils were used with other types of distractors (e.g., wrong action, foils to the subject or to the object.

Given that the SPM paradigm and similar procedures (e.g., sentence-picture verification, actor identification) provide categorical data in terms of counts of correct and incorrect responses, the possible outcomes are as follows:

- Performance is either *above chance* when patients point to the correct picture and ignore the proposed alternative(s) significantly more often than would be expected to happen by chance.
- *At chance* when correct and foil picture(s) are considered essentially equally often (i.e. when accuracy is not significantly different from the chance value).
- *Below chance* when mostly the incorrect picture(s) is/are selected.

Many studies that collected categorical data have reported a set of so-called core data of sentence comprehension in aphasia (e.g., Caramazza & Zurif, 1976; Mitchum & Berndt, 2008; Schwartz, Saffran, & Marin, 1980). This core set consists of a dissociated pattern for the comprehension of reversible canonical and non-canonical structures. Specifically, for reversible sentences with a canonical word order (e.g., actives, subject-relatives, or subject clefts) above chance performance was found whereas chance performance was observed in sentences with a non-canonical order (e.g., passives, object-relatives, or object clefts). Such a canonicity effect has been reported not only for English but for various other languages as well (e.g., Burchert & De Bleser, 2004; Burchert et al., 2003; Garraffa & Grillo, 2008). Below chance performance, on the other hand, was observed only rarely (e.g., Grodzinsky, 1995a).

A canonicity effect similar to the one seen in aphasia has also been observed in language-unimpaired participants. The effect in control participants, however, is not observed in terms of accuracy as in aphasic participants (although error rates in non-canonical sentences can indeed be higher compared to canonical sentences). Instead, higher reaction times for non-canonical sentences are reported, an observation indicating that non-canonical structures are generally harder and take longer to process than canonical sentences (Bornkessel, Schlesewsky, & Friederici, 2002; Gorell, 2000; Hanne, Sekerina, Vasishth, Burchert, & De Bleser, 2011; Hemforth, 1993; Schriefers, Friederici, & Kuhn, 1995).

CHANCE PERFORMANCE AND ITS INTERPRETATION

Categorical data of correct and incorrect responses are used to classify the actual performance of a person with aphasia as impaired or unimpaired, an interpretation that is biased by the design of the SPM task. If a participant demonstrates above chance performance with predominantly correct responses, the result is taken as evidence of normal-like parsing mechanisms. Chance or below chance performance with occasional or rare correct responses, on the other hand, is interpreted in terms of a breakdown in sentence comprehension (e.g., Caplan, 2001). Crucially, a correct response observed in an overall chance performance pattern is not regarded as the result of an unimpaired sentence processing mechanism but as being only *accidentally* correct.

To provide a theoretical account for the core data in aphasic sentence comprehension, researchers working in the framework of transformational theories of grammar have argued that a chance performance pattern could be the result of incomplete syntactic representations (e.g., Grodzinsky, 1995a, 1995b; Mauner, Fromkin, & Cornell, 1993). Specifically, an influential claim by Grodzinsky (1995b, 2000) was that traces of dislocated constituents are immediately deleted after having been generated initially, i.e., the Trace Deletion Hypothesis (TDH henceforth).[1] Furthermore it was argued that the degradation in syntactic representations in terms of deleted traces prevents the patient from correctly assigning the thematic role to the displaced constituent with the result of an erroneous sentence interpretation. The reason for this misinterpretation is a purported adoption of a heuristic strategy that performs the assignment of a thematic role to the displaced constituent on the basis on the most common word order in a language, i.e., the *AGENT-first strategy* in subject initial languages.

In non-canonical sentences such as passives in which the object is dislocated and its trace is deleted, two constituents become potential AGENTS in the event: the moved object in the sentence initial position due to the AGENT-first strategy, and the subject because of an intact thematic role assignment within the *by*-phrase. As a result, in the TDH framework, an individual with sentence comprehension deficits is faced with a thematic ambiguity, makes a guess by randomly choosing between two alternative sentence interpretations and, hence, performs within chance range. In canonical sentences, in which the subject is displaced[2] but still appears sentence initially, no such ambiguity arises. Instead, the adoption of the AGENT-first strategy successfully overrides the effect of deletion of the subject trace. Therefore comprehension remains above chance despite the assumption of impaired underlying syntactic representations.

[1]The TDH is based on transformational theories of grammar (e.g., Chomsky, 1986). These assume that non-canonical structures are derived from canonical sentences by moving the object from its base position adjacent to the verb and after the subject to the sentence initial position leaving behind a gap filled with a trace *t* (or copy).

[2]According to the VP-internal subject hypothesis (Koopman & Sportiche, 1991) the subject is moved from its position inside the VP to a higher node in the syntactic tree in the derivation of a sentence.

The theoretical framework of the TDH, however, was challenged on the ground that its predictions were almost strictly limited to the core performance pattern of above chance for canonical and chance performance for non-canonical sentences, a pattern that turned out not to be reliably replicable. In fact, accumulating evidence was reported about individuals with aphasia displaying a pattern that did not conform to the expected chance performance on non-canonical sentences. Instead, it was *above* chance. The systematic review by Berndt, Mitchum, and Haendiges (1996) is an often-cited paper in this respect, reporting above chance performance on non-canonical passive sentences in about one third of the aphasic patients surveyed. A similar high degree of heterogeneity was observed in other studies too. These inconsistencies subsequently led to a debate about chance performance in aphasia, a controversy that was about whether the existence of such patients proves that the TDH hypothesis is wrong (e.g., Berndt & Caramazza, 1999; Caplan, 2001; Caramazza, Capasso, Capitani, & Miceli, 2005; Caramazza, Capitani, Rey, & Berndt, 2001) or whether the conflicting evidence can be accommodated into the TDH framework without changing its core assumptions (Drai & Grodzinsky, 1999, 2006; Drai, Grodzinsky, & Zurif, 2001; Zurif & Piñango, 1999).

We believe that the TDH and the debate of it were misled in one critical aspect: it almost entirely focused on behavioural *offline* data, not considering the comprehension process as unfolding routines in real-time language processing. Moreover, the TDH accepted chance performance as a manifestation of an overall breakdown in sentence comprehension and implicitly assumed that chance performance reflects the *online* strategy of guessing. As the TDH was mainly based on behavioural offline data alone, however, the hypothesis was not well motivated, nor were subsequent theoretical conclusions about sentence comprehension deficits in aphasia. In fact, emerging evidence from sentence processing studies using online methods of a particular type and looking at real time processing suggests that the correspondence "chance = guessing" does not necessarily hold.

In the following sections we first give a short introduction to an important psycholinguistic method for studying language processing online—the visual world paradigm—and then provide a review of recently published data on sentence comprehension from studies using the visual world paradigm or similar techniques in aphasia. Finally we will propose an alternative interpretation of chance performance in sentence comprehension in the discussion section.

LANGUAGE PROCESSING AND THE VISUAL WORLD PARADIGM

The visual world paradigm was originally adopted as a psycholinguistic experimental method to investigate how language users integrate linguistic information with information derived from their visual environment (Huettig, Rommers, & Meyer, 2011). The paradigm capitalises on the recording of eye movements during spoken language processing. Importantly, it is different from eye tracking during reading, as it is not the eye movements on written words that are being measured. Instead the time course and the pattern of fixations to potential referents in the participants' visual field (usually displayed on pictures or scenes) are used to draw inferences about processing of spoken linguistic input that is somehow related to the visual material presented.

Variants of the paradigm use real-world objects instead of pictures (e.g., Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995), a combination of spoken and written language comprehension (Huettig & McQueen, 2007), or investigate spoken language production (e.g., Gleitman, January, Nappa, & Trueswell, 2007; Griffin & Bock, 2000; Meyer, Sleiderink, & Levelt, 1998).

Allopenna, Magnuson, and Tanenhaus (1998) introduced the term visual world paradigm. However, the basic methodology had already been used in the 1970s (Cooper, 1974) before Tanenhaus et al. (1995) revived it in a study looking at processing of spoken sentences with temporarily ambiguous phrases. According to Tanenhaus, Magnuson, Dahan, and Chambers (2000) the strength of the paradigm is that it provides insights into online reference resolution in natural tasks. Boland (2004) points out that it is an excellent method to investigate temporal and qualitative aspects of language processing. Specifically, the eye-tracking method provides a window into the different stages of the unfolding language comprehension process in real time. The reason for the paradigm's excellent representation of online language processing lies in the fact that humans are equipped with a strong, innate, and unconscious tendency to immediately fixate referents corresponding to the words they hear (Carreiras & Clifton, 2004). In addition, there is evidence that non-linguistic visual information immediately affects the initial structuring of linguistic input (Knoeferle & Crocker, 2007; Tanenhaus et al., 1995) pointing to a very fast interaction of language processing and eye movements.

THE VISUAL WORLD PARADIGM IN APHASIC SENTENCE COMPREHENSION STUDIES

Online methods such as the visual world paradigm have recently also been adopted as a tool in neurolinguistics to investigate manifestations of language breakdown in different populations, e.g., in children with Specific Language Impairment (Hestvik, Schwartz, & Tornyova, 2010; Marinis & van der Lely, 2007) and, importantly, also in adults with aphasia. The advantage of taking unfolding processing mechanisms into consideration is that offline tasks (e.g., the SPM paradigm) only consider the end product of the comprehension process, which is chance performance. However, as already pointed out by Caplan, Waters, Dede, Michaud, and Reddy (2007), possibly both residual online processing abilities and compensation strategies could have contributed to this end product, and these contributions are undisclosed if the offline response is considered in isolation. The visual world paradigm, on the other hand, investigates a number of online mechanisms such as lexical access, lexical integration, syntactic parsing, and meaning assignment, all mechanisms that are concealed in experiments looking at offline comprehension in isolation. In fact, recently published data from eye-tracking studies using the visual world paradigm with individuals with aphasia and studies measuring movements participants perform with a computer mouse while producing responses to spoken sentences (i.e., mouse tracking) have consistently and unanimously demonstrated that as soon as the online perspective is taken into consideration, it becomes clear that the offline chance behaviour does not adequately reflect what happens during online sentence processing in aphasia but masks residual processing abilities (e.g., Caplan, Levy, & Michaud, 2010; Choy & Thompson, 2010; Dickey, Choy, & Thompson, 2007; Dickey & Thompson, 2009; Hanne, Sekerina, Vasishth, Burchert, & De Bleser, 2011; Meyer, Mack, & Thompson, 2012; Thompson & Choy, 2009; Yee, Blumstein, & Sedivy, 2008).

In the next sections we provide a review of different results of recent online studies that investigated sentence comprehension in aphasia by using the visual world paradigm or similar techniques.

Studies using the classical visual world paradigm

Dickey et al. (2007) used the classical psycholinguistic visual world paradigm and adapted it to a study with aphasic listeners. In their experiment, participants ($n = 12$ people with aphasia and $n = 8$ aged-matched healthy individuals) were asked to listen to a story in which a reversible event (e.g., a story of a boy kissing a girl at school) was introduced. At the same time the participants looked at a panel of four different pictures showing (a) the animate members involved in the transitive event (i.e., the subject/AGENT = boy and the object/THEME = girl), (b) the event's location (i.e., a school), and (c) an unrelated object as distractor (e.g., a door). In a comprehension probe following the introduction participants were asked to respond aloud to the auditory presentation of object *wh*-questions[3] (e.g., *Who$_i$ did the boy kiss t$_i$ that day at school?*) and their eye movements were recorded while they listened to these non-canonical structures. Proportions of fixations to the different pictures in the panel were calculated for different regions of interest in the non-canonical sentences, namely at the subject (*the boy*), the verb (*kiss*), the trace/object (*t$_i$ that day*), and the location region (*at school*).

The results of Dickey et al.'s study showed that behaviourally, i.e., in the distribution of correct and incorrect responses to the object questions, the control participants scored well above chance on non-canonical object *wh*-questions whereas the aphasic participants performed within chance range, a finding that is in line with results from other behavioural studies and confirms the predictions of a syntactic breakdown in aphasic sentence comprehension. Analysing the participants' eye movements, however, the authors found that during online processing, control participants looked at the picture depicting the object (*the girl*) at the region of the trace/object immediately after the verb, i.e., the control group associated the position of the gap/trace position with its filler/antecedent. Similar results were also obtained in other eye-tracking studies with healthy participants (e.g., Sussman & Sedivy, 2003), suggesting that gap-filling effects are an integral part of normal syntactic processing routines (see also Swinney & Fodor, 1989; Swinney & Osterhout, 1990). Interestingly, people with aphasia displayed the same gap-filling effects at the region of the trace/object. This finding of an object advantage in fixations at the position of the gap/trace hints at a successful, normal-like syntactic analysis in aphasic sentence comprehension and is not compatible with the notion of deleted traces, hence with the assumption of an overall syntactic breakdown in sentence comprehension in aphasia. Furthermore, when analysing the aphasic participants' correct and incorrect responses separately, Dickey and colleagues found that similar gap-filling effects could be observed in both correct and incorrect responses. However, when participants responded incorrectly, the eye movement patterns were different from those in correct responses as fixations shifted away from the picture of the object at the gap-site region to the AGENT/subject picture (*the boy*) at the sentence final location region, a dissimilarity that eventually resulted in an erroneous response to the object-question. The reliability of successful antecedent-gap computations in aphasic sentence comprehension was also demonstrated in further studies reporting similar gap-filling effects for other non-canonical structures like object relative clauses (Dickey & Thompson, 2009), for pronominal

[3]In addition to *wh*-questions, Dickey and colleagues also used yes-no questions and object clefts as comprehension probes. For the sake of simplicity we only report the results that are important for the purpose of this review.

resolution (Thompson & Choy, 2009) and for the processing of reflexives (Choy & Thompson, 2010).

Taken together, the findings of studies using the classical visual world paradigm indicate that the processing routines underlying correct and incorrect offline responses are different: they are normal-like with successful and timely antecedent-trace/gap computations when the output is correct. They are dissimilar when responses are incorrect. In unsuccessful attempts of processing non-canonical sentences, a subject-advantage emerges in the sentence final region. This can be interpreted as an intrusion of the animate subject as a competitor to the successfully retrieved object filler/antecedent at the gap-site in the interpretation of a reversible event (Dickey et al., 2007). Sentence processing therefore becomes highly vulnerable to intermittent interferences of a normally impermissible interpretation due to an occasionally impaired integration of the successfully retrieved object filler/antecedent into the semantic representation of the sentence (cf., the *lexical integration problem* as in Choy & Thompson, 2010).

Studies combining the visual world paradigm with sentence–picture matching

Hanne et al. (2011) were the first to combine the visual world paradigm and the SPM task to investigate the comprehension of canonical and non-canonical sentences in aphasia (cf., Stromswold, Eisenband, Norland, & Ratzan, 2002, for the use of the same experimental design in a study with healthy adults and children). In Hanne et al.'s combined task, German-speaking aphasic participants ($n = 7$) and control participants ($n = 8$) were presented auditorily with reversible canonical subject-verb-object (SVO) and non-canonical object-verb-subject (OVS) test sentences together with a target and a foil picture (the SPM task) and, simultaneously, the participants' eye movements were recorded according to the visual world paradigm. In the analysis of the eye movements the proportion of fixations to the target and the foil picture was calculated for different auditory regions of interest in the test sentences, i.e., the regions of NP1, the verb and NP2 as well as the region of silence at the offset of the noun-verb-noun test sentences. The instruction in this task was to identify the picture corresponding to the heard sentence.

It is important to note that the combination of the visual world paradigm with the SPM task cannot directly detect gap-filling effects as a reflection of successful syntactic parsing as in the visual world paradigm. In fact the combined task requires the participant to identify the correct picture of an action in which more than one person is depicted instead of a single referent. A successful identification of the target picture, therefore, is the result of both the retrieval of the filler at the gap-site (i.e., syntactic processing) and the integration of the successfully retrieved filler into a representation for thematic interpretation in order to select the target picture (cf. Meyer et al., 2012, for a similar argumentation). However, Hanne and colleagues hypothesised that if the conclusion from previous online studies is correct that syntactic parsing is basically intact in people with aphasia and poor sentence comprehension results from intermittent parsing deficiencies, one would again expect distinct processing routines for correct and incorrect responses rather than a single mechanism of guessing as suggested by the TDH. Furthermore, distinct processing routines should be reflected by different eye movement patterns depending on the accuracy of the response: normal-like patterns in correct responses and patterns that are qualitatively different in incorrect responses.

Indeed, the results of Hanne et al.'s investigation revealed that while the behavioural performance of the aphasic participants corresponded to the core pattern predicted by the TDH (i.e., chance performance on non-canonical sentences), their eye movements were systematically related to the patterns of the control participants depending on the offline response accuracy. Overall, the results for both non-canonical and canonical test sentences showed that, in correct responses, the eye movement patterns of the aphasic participants were qualitatively not different from those of the control group. Specifically, in non-canonical OVS sentences, control participants showed a pattern of early and consistent fixations on the target picture that started at the verb-region immediately after NP1 and lasted until the silence region. The pattern in participants with aphasia was exactly the same when their offline response to non-canonical OVS sentences was correct. In canonical sentences, on the other hand, control participants consistently fixated the target picture starting at the object NP2-region. Again, a qualitatively similar fixation pattern was observed in the aphasic participants for correct responses to canonical SVO sentences, although the target picture advantage occurred later than in control participants, i.e., in the silence-region.

When the offline response was incorrect, the aphasic participants' eye movements consisted of unstable and inconsistent fixation patterns that were systematically different from the patterns observed in the correct responses where they were normal-like. These inconsistent patterns were observed in all incorrect responses and independently of the canonicity of the sentence.

A separate analysis of the aphasic participants' individual data (Hanne et al., 2012) revealed that six out of the seven patients corroborated the initial finding of distinct processing routines in aphasia as a function of response accuracy, i.e., when the offline response was correct, normal-like online sentence comprehension mechanisms could be observed. Non-normal-like mechanisms were observed in case of incorrect responses. In only one patient was an eye movement pattern detected that was indicative of a single processing routine and resembled a guessing strategy.

In another study combining the visual world and the SPM paradigm, Meyer et al. (2012) investigated the comprehension of a further type of non-canonical sentences, namely passives in comparison to active sentences, in a group of individuals with aphasia and age-matched controls (each $n = 10$). Their participants saw a pair of two pictures and simultaneously heard a reversible sentence, i.e., either a canonical active or a non-canonical passive sentence. The regions of interest in the sentences for the analysis of the eye movements in this study were: (1) beginning of the sentence to onset of NP1, (2) onset of NP1 to onset of verb, (3) onset to offset of verb, (4) offset of verb to onset of NP2 and (5) onset of NP2 to end of trial. Thus, in a passive sentence, the regions were: (1) *The* (2) *man was* (3) *shaved* (4) *by the* (5) *boy*. Eye movements in correct and incorrect responses were analysed separately.

The results of Meyer et al.'s study showed again that there are different processing routines producing correct and incorrect responses. In active sentences control participants started to show a consistent advantage for the target picture at the verb in region 3 until the end of the trial. In earlier regions a significantly reliable preference for one of the pictures could not be observed. The aphasic participants displayed a qualitatively similar fixation pattern in active sentences when their response was correct, although the target picture advantage was delayed and only occurred at the region of NP2 at the end of the sentence. When the response was incorrect, the fixation pattern of the aphasic participants was different and consisted of a significant advantage for the foil picture at the region of NP2. In passive sentences control participants displayed an agent-first bias at the regions of NP1 and the verb, i.e., they consistently fixated the foil picture. But as soon as they heard the by-phrase in region 4, fixations shifted to the target picture and remained there until the end of the sentence. A similar agent-first bias at the sentence initial regions was not present in the aphasic participants. However, when their response to a passive sentence was correct they showed a significant target picture advantage, just as the control participants did, but in a delayed fashion, i.e., at the region of NP2 after the by-phrase. In incorrect trials aphasic participants significantly more often preferred the foil to the target picture as soon as they heard the by-phrase.

Taken together, the findings of studies using the combined visual world and SPM paradigm indicate that the processing routines underlying correct and incorrect offline responses are different: they are normal-like (but delayed) when the output is correct. And they are different when responses are incorrect. Overall, these results are difficult to reconcile with a purported general guessing strategy in aphasic sentence comprehension. In such a case one would not expect systematic differences in online mechanisms resulting in correct and erroneous offline responses. Furthermore, if individuals with aphasia made a random choice, early and stable fixations of the correct picture as demonstrated above for non-canonical OVS sentences in Hanne et al.'s study would not be predicted. The fact that eye movement patterns in correct trials are qualitatively normal-like but often delayed is possibly a result of the two tasks being involved in the combined visual world and SPM paradigm. First, an antecedent for the trace at the gap-site needs to be retrieved and second, this antecedent has to be integrated into a thematic representation for sentence interpretation and picture identification. In classical visual world studies, where gap-filling is required in isolation, no such delay has been observed.

OTHER ONLINE METHODS IN RESEARCH ON APHASIC SENTENCE PROCESSING

Studies that also tapped online sentence processing mechanisms in aphasia but used different (although similar) methods as the visual world paradigm have reported corroborating evidence for normal-like sentence processing routines. An example is Caplan et al. (2007) who let aphasic participants perform a self-paced listening task before categorical data were collected. The authors found strong resemblances with normal-like online processing mechanisms for correct responses in participants with aphasia, similarly to the results reported above. Incorrect offline responses, on the other hand, reflected online routines that were different and were marked by abnormal patterns in listening times. Similarly, in a mouse-tracking study (Caplan et al., 2010), in which movements of computer mice (supposedly reflecting mechanisms of online syntactic structure assignment) were measured while participants made responses to spoken sentences in three different tasks (i.e., SPM, actor identification, and a computer based-version of enactment), the results suggested that, when the participants' responses were correct, their mouse movements resembled control-like patterns. Only when errors were made did data indicate an incorrect structure assignment pointing to aberrant sentence-processing mechanisms.

The visual world and related online paradigms as reported above, are certainly not the only psycholinguistic online methods that were adapted for individuals with aphasia in order to test comprehension of sentences involving dislocated constituents and traces. A number of authors capitalised on a technically different method: the cross-modal lexical decision task (CMLD). However, this method does not collect categorical data of correct and incorrect responses in sentence comprehension probes of the structures used in the CMLD experiments and therefore cannot contribute directly to the re-examination of the concept of chance performance in aphasia, which is the focus of this review.

In the CMLD task participants listen to sentences and, at some point in these sentences, a string of letters is visually presented on a computer screen while participants are asked to decide whether this letter string is a word or not by pushing a button (lexical decision task). Importantly, lexical decision in general is facilitated when the target word is primed by semantically related word. The CMLD paradigm takes advantage of this well-established priming effect and predicts for Broca's aphasia that if—as has been shown for unimpaired listeners—dislocated constituents are immediately reactivated at their trace/gap-site (Swinney & Fodor, 1989; Swinney & Osterhout, 1990), priming effects should be observed when a letter string representing a word is presented at the gap-site that is semantically related to the dislocated constituent. Several studies (e.g., Swinney & Zurif, 1995; Zurif, Swinney, Prather, Solomon, & Bushell, 1993) tested this prediction and reported that while individuals with Wernicke's aphasia do show the expected priming effects at the gap-site, individuals with Broca's aphasia do not. Such an absence of priming effects restricted to Broca's aphasia was originally interpreted as consistent with the hypothesis of deleted traces (TDH) and impaired syntactic processing. Later studies, however, demonstrated that, although reactivation of the antecedent of the trace may be absent at the trace/gap-site, the effect can still be observed in Broca's aphasia, although in a delayed fashion at later points in the sentence (Burkhardt, Pinango, & Wong, 2003; Love, Swinney, Walenski, & Zurif, 2008; Love, Swinney, & Zurif, 2001). Interestingly, gap-filling effects similar to those of unimpaired listeners can still be found in Broca's aphasia when sentences are presented with a slower-than-normal speech rate and, therefore, with a gap-site that is longer lasting (Love et al., 2008). Furthermore, the finding of Thompson and colleagues that eye-tracking experiments reveal timely gap-filling effects at the trace-site (cf. above) are only apparently in opposition to the delayed antecedent reactivation effects in CMLD tasks. Love et al. (2008) argue that the sentence presentation rate in the eye-tracking experiments by Thompson and colleagues did not correspond to a normal rate but was similar to (if not even slightly slower than) the slowed speech rate in Love et al. (2008).

AN ALTERNATIVE INTERPRETATION OF CHANCE PERFORMANCE

Based on our review of the results of studies that have used the visual world and related paradigms, we argue for a reinterpretation of the concept of chance performance in the debate about sentence comprehension disorders. Chance performance may not necessarily be the result of a single, impaired processing mechanism, i.e., a guessing strategy in which responses, independently of being correct or incorrect, are a product of chance. Instead, studies using different online methods have revealed that the nature of sentence parsing mechanisms in aphasia is twofold: they are either normal-like and produce correct responses or they are impaired leading to incorrect responses. Behaviourally, these distinct processing routines cause what, at face value, appears to be like the tossing of a coin. Cognitively, however, they suggest a new interpretation of categorical data: above chance performance can be the result of predominant normal-like processing routines with occasional intermittent deficiencies leading to some incorrect responses. Chance and below chance performance, on the other hand, reflect gradient increases of breakdowns in (otherwise normal-like) parsing mechanisms due to accumulating deficiencies producing incorrect responses. However, even under these circumstances of increasing breakdowns, correct responses remain the product of normal-like processing mechanisms, i.e., correct responses in an overall chance or below chance performance pattern are not accidental.

This new interpretation of categorical data does not preclude the possibility that chance performance may be caused by a true guessing strategy. In fact, the individual eye movement pattern of one of the aphasic participants in Hanne et al. (2011) indicated that such a strategy was adopted as a last resort, possibly as the result of parsing mechanisms that were too weak to produce any outcome. This reinterpretation of the concept of chance performance is also compatible with the observation that chance performance is not restricted to non-canonical sentences but is occasionally also observed in canonical structures (e.g., Badecker, Nathan, & Caramazza, 1991; Schwartz et al., 1980; Sherman & Schweickert, 1989). However, as noted earlier, non-canonical sentences are generally harder to process and are therefore more vulnerable to deficiencies than canonical sentences.

An important question that needs further research before a satisfactory answer can be found is what exactly causes intermittent deficiencies in aphasic processing routines. Possibly, intermittent deficiencies can be induced by increasing task demands, syntactic complexity and/or limitations in working memory (cf. Caspari, Parkinson, LaPointe, & Katz, 1998; Friedmann & Gvion, 2003; Wright, Downey, Gravier, Love, & Shapiro, 2007). This issue, however, is beyond the scope of this paper.

CONCLUSION

Our conclusion is that the consideration of behavioural offline data alone may not be sufficient to evaluate a performance in language tests and draw theoretical conclusions about language impairments. Rather it is important to call on additional data from online studies looking at language processing in real time to understand a performance at the behavioural level and the nature of eventual underlying deficits.

For clinical practice, the consideration of online data showing that sentence comprehension can be normal-like, even if performance, at face value, is at chance has important implications for any therapy targeting impaired sentence comprehension abilities. If syntactic parsing mechanisms are in principle spared in aphasia, therapy focusing on training of retained resources rather than on complete re-learning of grammatical principles should be more efficient (cf., Stadie et al., 2008; Thompson, Shapiro, Kiran, & Sobecks, 2003).

The application of online experimental methods has a potential impact not only for impairments in sentence processing but also for other aspects of language breakdown in aphasia. For example, the online study of disorders in single-word comprehension and semantic difficulties could yield new insights regarding the underlying cause of such impairments in lexical access and lexical-semantic integration. Also, with respect to language production, online methods like the visual world paradigm offer potential premises in uncovering fine-grained details about the exact point of breakdown in the cognitive mechanisms responsible for real-time message generation.

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