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Establishment of a Phonemic Clustering System for American Sign Language

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Abstract: Executive functioning, the self-regulatory or control system that governs all cognitive, behavioral, and emotional activity, may be measured by means of a variety of psychological and neuropsychological tests, including tests of verbal fluency A subset of these tasks, phonemic fluency, requires a person to generate words based on a letter cue (e.g., words that begin with the letter f). However, such tests are designed for users of spoken language. This article reports on the use of a measure of verbal fluency for American Sign Language (ASL) for which, in addition to the traditional score based on the total number of words produced during the task, an analysis of ASL-based "clusters" (related signs produced in succession) and "switches" (transitions from one cluster to another) was developed. Previous research with standard verbal fluency tasks has suggested that cluster and switching analysis reflects mental flexibility and cognitive search skills. A system for analyzing phonemic clusters in ASL is described, and its application is demonstrated using a case example. [PUBLICATION ABSTRACT]

Full text: Headnote

Abstract

Executive functioning, the self-regulatory or control system that governs all cognitive, behavioral, and emotional activity, may be measured by means of a variety of psychological and neuropsychological tests, including tests of verbal fluency A subset of these tasks, phonemic fluency, requires a person to generate words based on a letter cue (e.g., words that begin with the letter f). However, such tests are designed for users of spoken language. This article reports on the use of a measure of verbal fluency for American Sign Language (ASL) for which, in addition to the traditional score based on the total number of words produced during the task, an analysis of ASL-based "clusters" (related signs produced in succession) and "switches" (transitions from one cluster to another) was developed. Previous research with standard verbal fluency tasks has suggested that cluster and switching analysis reflects mental flexibility and cognitive search skills. A system for analyzing phonemic clusters in ASL is described, and its application is demonstrated using a case example.

Executive functioning is defined as the self-regulatory or control system that governs all cognitive, behavioral, and emotional activity (Denckla 1996; Anderson 2008; Hauser, Lukomski, and Hillman 2008). Aspects of executive functioning include initiating activity, inhibiting behavior, shifting between tasks, planning and organizing, selecting goals, and monitoring and evaluating behavior, among others (Gioia et al. 2000).

Certain aspects of executive functioning are commonly measured by tests of verbal fluency. The two main types are phonemic fluency tests (e.g., controlled oral word association [COWA] tasks) and semantic fluency tests. In a COWA test, a person must generate words in response to a letter cue. For instance, if individuals are asked to provide words that begin with the letter l, they might respond with "lion" or "learn." A test of semantic fluency measures a persons ability to produce words in response to a categorical cue (Baron 2004; Strauss, Sherman, and Spreen 2006). For example, if given the category animals, individuals might respond with "dog," "cat," or "mouse."Verbal fluency tests are thought to demonstrate a persons level of lexical organization, and these tasks involve many mental processes in their successful completion.They appear to involve (1) immediate attention to initiate the generation of words, (2) an available word knowledge (i.e., semantic/lexical system) from which to select, (3) the ability to retrieve from verbal declarative memory, and (4) an executive ability to coordinate this process, including working memory to monitor performance and avoid breaking the rules (e.g., no proper nouns)

(Ruff et al. 1997). Individuals are also required to understand and remember task directions/parameters in order to successfully complete these tasks.

The FAS is the most commonly used measure of COWA and is widely employed for both research and clinical purposes (Barry, Bates, and Labouvie 2008). In the common administration of this task, participants are asked to produce as many words as possible that begin with a certain letter within one minute: "I will say a letter of the alphabet.Then I want you to give me as many words that begin with that letter as quickly as you can. For example, if I say ?b,' you might give me ?bad,' ?battle,' and ?bed.' I do not want you to use words that are proper names, such as ?Boston,'?Bob,' or ?Buick.' Also, do not give me the same word with different endings, such as ?eat' and ?eating.' Any questions? (pause) Begin when I say the letter.The first letter is f. Go ahead" (Strauss, Sherman, and Spreen 2006, 502).

Until recently, very little research has studied verbal fluency in individuals who are deaf or hard of hearing. Analyses by Morere, Witkin, and Murphy (2012), using a signed administration of the task, compared the number of words (signs) that deaf and hard of hearing college students produced on a COWA task (FAS) to published metanorms based on results from hearing people and found that the deaf and hard of hearing students produced more than one standard deviation fewer words than their hearing peers. Several factors may explain this result, including the impact of English proficiency, vocabulary size, translation demands (the participants were asked to think of English words and produce the most nearly equivalent sign), and bilingualism, but these results indicate that counting the total number of words produced during these tasks may not fully and accurately reflect the verbal fluency of deaf and hard of hearing individuals. In light of these shortcomings, a fluency task that may be more appropriate to use with deaf and hard of hearing populations was developed, and this article describes that task and presents the development of a novel scoring system that is sensitive to the unique linguistic and psychological qualities of this population.

Sign-Based Verbal Fluency: The 5-I-U

In order to determine whether a sign-based fluency measure is more appropriate for use with deaf populations, the Science of Learning Center onVisual Learning andVisual Language's (VL2) Psychometric Toolkit team developed an ASL-based phonemic fluency measure called 5-I-U (Morere, Witkin, and Murphy 2012).The 5-I-U task is similar to the standard verbal fluency task (FAS), except that instead of using letter prompts, the participant is asked to generate signs using specific ASL handshapes (figure i).This assessment was designed to recruit sign-based strategies comparable to those used on the letterbased task. For a more detailed description of the development of this measure and the rationale behind the handshapes chosen, please refer to Morere, Witkin, and Murphy (2012).

Scoring of Verbal Fluency Tasks

Although it is common to simply count the number of words produced during a COWA task, this is not the only way to interpret the results of this measure. Emerging research indicates that multiple factors are involved in successful performance. If those additional factors are not investigated, important information about an individuals executive functioning or the underlying cognitive processes involved in successful completion of the task may be missed. Studies have increasingly examined the degree to which people generate words within semantic or phonemic clusters (Troyer, Moscovitch, andWinocur 1997; Auriacombe et al. i993;Troyer 2000; Ross 2003). Loosely defined, a cluster is a group of phonemically or semantically related words produced in succession. In addition to clusters, studies have also examined the number of transitions between clusters as a measure of mental flexibility (Baron 2004). A person must be able to mentally search through related words that fit the task parameters, produce them, recognize when they are struggling to produce more words, and subsequently switch to a new cluster with a different pool of responses. To efficiently generate a large number of words, a person must effectively use both clustering and switching and find a balance between these strategies.

Troyer, Moscovitch, andWinocur (1997) designed a system to measure the use of clustering on phonemic fluency tests. According to their criteria, a cluster involves multiple consecutive responses that (a) begin with the same two letters, such as arm and art, (b) rhyme, such as sand and stand, (c) differ by only a vowel sound regardless of the spelling of the word, such as sat, seat, soot, sight, and sought, or (d) are homonyms (i.e., words with two or more spellings, such as sum and some), if indicated by the participant. Errors and repetitions are included since they indicate neural activation of a particular concept.

Stokoe's ASL Phonology

In order to develop a method of determining clusters in ASL responses, a basic understanding of the phonology of signs is required. The first attempt to systematically describe the sublexical structure of signs used in signed languages based on linguistic principles (i.e., similar principles by which words of spoken languages can be broken down into individual sounds) was undertaken by Stokoe, Casterline, and Croneberg (196$). The Dictionary of American Sign Language (DASL) details a way to describe signs in written form, thereby permitting the analysis of the parts of signs. Although alternative approaches to describing ASL phonology have been described (cf. Johnson and Liddell 2010, 2011 a, 2011b), Stokoe's analysis of ASL phonology was used for the purposes of the current scoring system.

Stokoe, Casterline, and Croneberg (1965) identified three parts or aspects of signs that need to be captured in written form. The first is the tabula, abbreviated tab, which indicates the place in which signs are produced.The second is the designator, or dez. This aspect indicates the shape the hand assumes in sign articulation. The third aspect of signs is the signation, or sig, which indicates the action of the hand. In more modern terms, these are known as the sign's location, handshape, and movement, respectively. We use Stokoe et al.'s terms to describe these aspects of signs.

Of the fifty-five symbols used to describe parts of signs, twelve refer to the sign's place of articulation. Crucially, location symbols capture the fact that signs can be articulated in neutral space (i.e., the space in front of or to the side of the signer's body), as well as on the opposite arm, the torso, or the face/head.

The handshape parameter can be characterized by one of nineteen possible symbols. Readers who are familiar with fmgerspelling in ASL will likely have an easy time understanding which handshapes correspond to the symbols; however, a bit of clarification is necessary. First, consider the handshape A; this designation is used for any fistlike handshape, which includes the letters a, s, and t of the manual alphabet, so the designation "A" is not completely unambiguous. Similarly, Stokoe et al. used the handshape G to describe any handshape in which the index finger is extended, including the manual letter d and the number l.To avoid confusion among participants, who may be unfamiliar with Stokoe et al.'s system, the VL2 team decided to refer to this handshape as 1. Consequently, the task is referred to as 5-l-U instead of 5-G-U, and task administrators use the numerical 1 handshape when introducing the task.This more accurately describes the handshape for which the task was designed; here, we refer to the handshape as a 1.

Another consideration is the fact that the distinguishing characteristic for some letter signs of the alphabet is not the hand configuration but the palm orientation (an aspect or parameter of signs that was suggested after the DASL was published; see Battison 1978). Examples of this include the letter pairs h and u,g and q, and k and p. Finally, two handshape names in Stokoe et al.'s system refer not to letters of the manual alphabet but to the shape the hand assumes when articulating different numbers; these are referred to as $ and 3 handshapes.

The remaining twenty-four symbols used in the DASL refer to the movements hands can perform in articulating signs. Some of these can be further divided into several subgroups based on the nature of the movement. These subcategories refer to vertical action, sideways action, horizontal action, rotation, and interaction of movement, in which the primary articulator moves toward the passive articulator (e.g., the other hand, head, or torso).

Rationale

Researchers and clinicians alike are recognizing that verbal fluency tests can provide valuable information about cognitive functioning and lexical organization beyond the total number of responses produced by a participant. Researchers have developed in-depth scoring systems designed to analyze search strategies, such as clustering and switching (Troyer, Moscovitch, and Winocur 1997).

Analyses by Morere, Witkin, and Murphy (2012) clearly demonstrate that traditional verbal fluency scoring methods are insufficient for use with signing populations. For example, they observed that, although the total number of correct responses produced on the semantic fluency tasks administered following the English-based FAS and the ASL-based 5-I-U were comparable, performances on the identical tasks correlated with a somewhat different set of measures depending on whether they were primed by the English- or the ASL-based phonemic fluency task. The FAS-primed animal fluency task correlated more highly and with a greater number of reading and other academic measures, while the comparable ASL-primed task correlated with more ASL-based tasks, including an ASL-based listlearning task. A similar pattern was seen for food fluency. This suggests that the underlying strategies used to achieve the comparable outcomes differed somewhat depending on the linguistic priming of the preceding task. Similarly, discrepancies occurred between the relationships of the FAS task and the 5-I-U with other toolkit measures. Indeed, factor analysis of a subset of complete data found that the FAS loaded with other executive functioning and working-memory tasks, while the 5-I-U produced a unique factor, with minimal loading on any other factor (Allen and Morere 2012a). However, although systems have been established to analyze participants' use of clusters and switches on verbal fluency measures, the manual nature of ASL means that these systems cannot be used to analyze signed responses.

The goal of this study was to develop a scoring system for clustering based on ASL phonology analogous to that ofTroyer, Moscovitch, and Winocur (1997) to enable higher-level analyses of verbal fluency tasks with signing populations.

Methodology

This study extracted archival data from theVL2 Psychometric Toolkit project. The project ran a total of forty-seven participants, thirtyseven of whom consented to allow videotaped data to be analyzed for other VL2 projects under the NSF Science of Learning Center (SLC) Cooperative Agreement # SBE054.1953.The participants were deaf college students attending an ASL/English bilingual university for deaf and hard of hearing individuals. Two-thirds (67.1 percent) of the sample reported congenital deafness, and another 8 percent reported becoming deaf by age 2. Thus, the majority of the participants were prelingually deaf. Despite a range of educational and linguistic backgrounds, 90.8 percent reported that ASL was their preferred language. Furthermore, an atypically high proportion (more than 25 percent of the participants) reported having at least one deaf parent. See Allen and Morere (2012b) for further information on the demographic characteristics of the sample.

The Psychometric Toolkit study was designed to help investigate the relationships among and establish reliability and validity data for a variety of cognitive, achievement, and executive functioning measures. The participants were administered a battery of tests, which included measures of phonemic fluency. Testing required two sessions of approximately three hours each, with a typical delay of one to two weeks between sessions.

During the VL2 Toolkit study, two measures of phonemic fluency were used. The first was designed to tap search strategies in English (FAS: participants must generate responses based on the initial letter of English words), while the second was designed to elicit ASL-based search strategies (5-I-U: as responses, participants were asked to generate signs that incorporated the ASL handshape used as a probe for that trial).The tests were administered according to the standard instructions (described earlier), except that for both FAS and 5-I-U, participants were asked to respond using ASL signs.

The measures administered during each testing session were counterbalanced both within and across sessions, resulting in eight potential two-session sequences. The testing sequences were established so that the 5-I-U and FAS tasks were administered during separate sessions, and the semantic fluency tasks were administered after each of the phonemic fluency tasks. To minimize the impact of test order on the results, the participants were randomly assigned to each condition. Assessments were administered by deaf graduate students fluent in ASL, and responses were videotaped. For the current analyses, the primary author and a trained assistant reviewed the responses for both phonemic fluency tasks and developed the current scoring system.

Establishment of an ASL Clustering System

Criteria were established for measuring ASL-based cluster use on linguistic fluency tasks using the phonemic parameters identified by Stokoe, Casterline, and Croneberg (1965) in order to produce a sign-based scoring system analogous to that of Troyer, Moscovitch, and Winocur (1997). During the initial analyses, trained evaluators watched videos of the participants and recorded the phonemes used for each sign produced. For the FAS task, this included the parameters of handshape, location, and movement. For the 5-I-U task, it was assumed that all of the signs would include the same handshape (as that was the prompt for the task), so initially, only location and movement of the hands were noted. Once it became apparent that signs occasionally used more than one handshape, however, it was decided that it was important to record handshape information for 5-I-U as well. Handshapes were recorded for both the dominant and nondominant hands, while the locations and movements were recorded only for the dominant hand. This decision is not without linguistic precedent. For example, in syllabic models of sign phonology (e.g., Brentari 1990), it is often assumed that the nondominant hand may either copy the movement of the dominant hand (making notation of the nondominant hand redundant) or remain stationary and thus serve as the place of articulation for the dominant hand. Finally, a record was made of the use of fmgerspelled words rather than lexical signs.

Analysis of clustering was based on the similarity of one phonemic parameter on two or more consecutive signs. For example, mother1 and sweet are both produced in the same location (defined by Stokoe, Casterline, and Croneberg as the lower face), and if they were produced in succession, they would be considered a cluster even though they have different movements and handshapes. Similarly, dance and vegetable have the same handshape even though the movement and locations are different and would be considered a cluster. It was determined that the phonemes involved in fingerspelling were not salient enough to be considered clustering, and as such, fingerspelled responses were recorded but excluded from clustering analysis.

It is important to note that clusters cannot cross parameters. Each parameter was assessed separately; the responses were first analyzed for clustering based on handshape, then on movement, and finally on location. It is possible for signs to fit into a cluster for multiple parameters; summer and dry use the same handshapes and the same movement and therefore qualify for clusters based on both criteria.

Following the methodology used by Troyer, Moscovitch, and Winocur (1997), cluster sizes were measured starting with the second sign in a cluster. So, if a cluster consisted of four signs, it would receive a score of "three." If a sign does not cluster with any other responses, it does not receive a cluster score (as the "cluster" consists of only one sign). By using this method, participants can receive a mean cluster score, as well as a total cluster score, for each phonemic parameter. Scoring the participants' responses using this system allows for comparison of the rates of clustering between different linguistic parameters, which in turn helps quantify the most salient characteristics involved in grouping signs.

Unexpected Challenges

In estabHshing a clustering system for analyzing ASL signs, we made every attempt to follow Stokoe, Casterline, and Croneberg's notation system as closely as possible; however, certain challenges required us to devise ad hoc solutions. In these cases, we attempted to base sign characterizations on linguistic principles, consistent with the foundation for the original DASL. For example, consider the sign dog pictured in figure 2. The DASL does not have a location "leg" or "thigh"; thus a "leg" placement was added to our inventory of possible places of articulation.

Additionally, some of the possible locations for the production of signs in Stokoe, Casterline, and Croneberg's system included the nondominant limb. Locations included the nondominant upper arm, the elbow or forearm, the wrist, and the back of the hand. Stokoe et al. did not, however, include the palm of the nondominant hand as a possible location, nor were the sides of the fingers included. This created some difficulty when attempting to code participants' responses. Examples from our data include name and hockey, pictured in figures 3a and 3b, respectively. Our participants produced these signs on the nondominant hand, yet this is not a possible location for a sign according to Stokoe et al. As opposed to the previous example, where Stokoe et al. did not include a location that accurately described ASL dog, these signs were best described using a neutral location. However, we felt that this information did not fully describe the signs' actual location.Thus, three locations were added to account for signs that are produced on the nondominant hand: one on the radial (thumb) side of the hand (e.g., name, figure 3a), one on the palm of the hand (e.g.,hockey,figure 3b),and one on the ulnar (pinky) side of the hand (e.g., magazine, figure 3c).

Two other issues regarding our coding practices deserve brief explication. The first has to do with linguistic information that we did not record, and the second has to do with complex signs that have more than one specification for any of the three parameters (placement, handshape, and movement).

ASL signs are often repeated in a process called reduplication. There are many reasons for this repetition; it may be used to add emphasis or to depict the duration of an event (e.g., lying-in-bed versus bedridden; Klima and Bellugi 1979), and it is also used to distinguish between noun/verb pairs like sit and chair (Supalla and Newport 1977) .Although linguists may be interested in the use of reduplication during verbal or signed fluency tasks, this information was not deemed relevant to the psychological purposes for which the signs were being recorded. In instances of reduplicated signs, the meaning the signer intended was recorded, but the movement was indicated only once.

Stokoe et al.'s notation system involves the use of "neutral space" as a location. During the analyses of signers' verbal fluency responses, we found that this was a common location in which participants produced signs. However, the exact location of this neutral space was inconsistent even in signs from the same signer. Signs were sometimes produced at shoulder height or in front of the chest or perhaps lower. Again, while the height of sign articulation may be relevant for linguistic analyses, this was not thought to have a significant impact on the psychological processes involved in the successful completion of the verbal fluency task and was thus not recorded.

Finally, we come to the issue of complex signs that have more than one specification for any of the three main parameters determined by Stokoe et al.This is not entirely surprising; we are breaking down the signs produced by the participants into phonemes, and each sign is made of multiple phonemes, just as English words comprise many phonemes. Signs often vary within the same parameter by changing handshape, movement, or location. Examples from our data include friend (1 -» X handshape), house (separate -» down movement), and dog (leg -» neutral location).

Even though the aforementioned clustering criteria were sufficient for a majority of the signs produced by our participants, these "complex" signs, which use multiple phonemes along the same parameter in a single sign, were unable to be fit into this paradigm. We decided to define a cluster as consecutive signs in which two or more phonemes were identical for each parameter. For example, friend changes handshape, from 1 -» X. If the participant produced friend followed by meet, which uses the 1 handshape only, this would not be considered a cluster. If the participant produced friend followed by dry, which also uses the 1 -» X handshape, then this would be considered a cluster.

Application of the Scoring System

In order to fully understand the complexities of this scoring system, we present a case example from one of our participants. This participant was administered the tests as described and, during the middle frame of the 5-I-U, produced thirteen signs (the English glosses are provided): sign, one, deaf, dream, corn, candy, enemy, LONELY, SINGLE, CRAZY, FRIEND, SOUR, WORM. The responses were scored according to the criteria, and the data are summarized in figure 4.

As shown, initial analysis focused on recording the handshapes, location, and movement of each sign. The English gloss was also recorded and may be used for future semantic clustering analysis.Thus, six charts were made for each participant, one for each phase of FAS and for 5-1-U. This allowed for uniformity in scoring and ease of comparing results. It is important to note that many signs did not use all of the parameters (e.g., some signs used only one hand and thus did not have a nondominant handshape); this is denoted by the word "none" in the corresponding column. Other important information (e.g., the nondominant hand was not visible during the last sign, and thus the handshape could not be discerned) was also recorded. Additionally, many signs can be signed in multiple ways; for example, deaf is often signed with the index finger pointing to the ear and then to the cheek, near the mouth. One participant, however, signed it by pointing to the cheek first and then to the ear. In recording all of the signs, special care was taken to ensure that the recording matched what the participants actually produced.

The next step of analysis was to focus on the clustering of handshapes. As the prompt for this task was to generate signs using the 1 handshape, this is relatively straightforward. The first six responses all use the 1 handshape exclusively; this results in a cluster score of five for this cluster (as the cluster score begins with the second response in the group). The next response, enemy, uses multiple handshapes: the 1 handshape and the person marker, which uses the B handshape. This pattern of handshapes is not used by the responses immediately preceding or following this sign, so it receives a cluster score of zero. The following three signs result in a cluster score of two, and the remaining three signs are not part of a cluster. Thus, this participant receives a total cluster score of seven for handshape on this part of the 5-1-U.The participant used an average of 0.54 clusters per response (a cluster score of seven divided by thirteen total responses).

Analysis of the location parameter follows a similar pattern. In this example, the first two signs both use a neutral location, while lonely and single both use the mouth/lips location.This results in a total cluster score of two and a cluster/response ratio of 0.15.

Analyzing the movement parameter is slightly more complicated since many signs incorporated many movements. According to our criteria for complex signs, consecutive responses are considered a cluster if two or more identical movements are involved in the production of the sign. In this example, enemy, lonely, and single all use the movements "touch" and "down."This results in a cluster score of two. friend and sour both use the movements "touch" and "supinate," resulting in a cluster score of one.This produces a total cluster score of three for the movement parameter and a cluster/response ratio of 0.23.

Discussion

Throughout this article, we have discussed various methods of interpreting the results of verbal fluency tests. Although the most common method of analyzing such results involves counting the total number of responses, researchers have begun interpreting the outcomes in different ways (see Raskin, Sliwinski and Borod 1992; Auriacombe et al. 1993; Troyer 2000; Abwender et al. 2001; Baron 2004). Troyer, Moscovitch, and Winocur (1997) developed a system to measure the use of clustering and switching on verbal fluency tests. This system has been used to assess higher-level executive functions (e.g., planning, inhibition) and lexical organization, and clustering and switching have been increasingly studied in neuropsychological literature.

Analyses by Morere, Witkin, and Murphy (2012) suggest that for deaf college students responding in ASL, reporting the total number of responses on fluency tasks is insufficient. Troyer et al.'s system, however, was unable to be adapted for use with signed languages, as the parameters focus on speech-based units.This article details an attempt to establish a system that allows verbal fluency results from signing populations to be analyzed in an empirical fashion comparable to the system developed by Troyer et al.

Admittedly, this system has some limitations. Notation based on work by Stokoe et al. provided a framework that enabled us to develop a coding system, but many shortcomings became apparent only after we had begun coding responses. Even though adjustments were made to account for unforeseen challenges, it is possible that other situations exist that we did not encounter and thus were not able to address. In addition, some of the decisions detailed here, such as establishing three "new" locations for sign production, may need to be revisited as the system is refined during further use. Furthermore, our analysis focuses on phonemic fluency (in this case, FAS and 5-I-U) but does not address semantic fluency Troyer et al. also developed a system to analyze clusters and switches on semantic fluency tests; additional research is needed to determine whether this system is appropriate for use with signing deaf populations or whether adjustments are necessary. Future research may also focus on expanding the subject pool in order to gather more information about the types of clusters used by deaf populations during cognitive searches.

At the surface level, the system of phonemic clustering described in this article affords researchers and clinicians an opportunity to analyze verbal fluency data from signing populations in a manner similar to that used with data from hearing, nonsigning populations. The creation of this system, however, also provides an opportunity for unique scientific exploration into the response patterns and cognitive search processes of bilingual and bimodal populations. In an increasingly heterogeneous society, the insights gained from additional study of this population may become more relevant since they may provide different perspectives about the human capacity for language learning, executive functioning, and cognitive flexibility.

Footnote

1. Per convention, glosses for signs are shown in small caps.This is to distinguish the mention of English words used to represent signs from the mention of English words themselves.

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