


RESEARCH ARTICLE

Intact fluency in autism? A comprehensive approach of verbal fluency task including word imageability and concreteness

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Abstract

Verbal fluency is a cognitive function reflecting executive functions and the ability to retrieve the appropriate information from memory quickly. Previous studies reported conflicting results—impaired and intact verbal fluency—in autism spectrum disorder (ASD). Most studies concentrate on overall word productivity, errors, perseverations, clustering, or switching. We used a comprehensive approach to evaluate the reported discrepancy in the literature and introduced a new angle using the concept of word abstraction and imageability. Moreover, we analyzed the performance in two-time intervals (0–30 s and 31–60 s) to assess the temporal dynamics of verbal fluency and a possible activation or initiation deficit in autism. Sixteen adults with ASD and 16 neurotypical control participants, matched by gender, age, and education level, participated in our study. Contrary to our expectations, we did not find a significant difference between groups in word productivity, the number of errors, clustering, or temporal dynamics, neither in semantic nor in phonemic fluency tasks. Surprisingly, the two study groups' performance did not differ in terms of imageability or concreteness characteristics either. Our results raise the possibility that verbal fluency performance is intact in autism. We also suggest using a comprehensive approach when measuring fluency in autism.

Lay summary: People with autism tend to think and communicate differently. In our study, we tested whether people with autism come up with more concrete or imageable words and whether their performance is better compared with neurotypicals in the beginning or in the later phase of a task measuring how many words they can produce in a minute. We did not detect any difference between the two groups; however, we recommend studying verbal fluency in autism from more and different angles in the future.

KEYWORDS

autism spectrum disorder, cognitive, concreteness, imageability, verbal fluency

INTRODUCTION

Autism spectrum disorder (ASD) is a neurodevelopmental condition diagnosed based on the diad of persistent deficit in communication, social interaction, and restricted,

repetitive patterns of behavior, interests, or activities (American Psychiatric Association, 2013). Autistic people may experience difficulties with planning, shifting, sustaining, or selecting attention, as well as response inhibition (Craig et al., 2016). Most commonly, symptoms are believed to be rooted in an impairment of executive functions (EF), which are necessary for regulating and

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controlling behavior (Pellicano, 2012). Impaired EF may contribute to the explanation of a lack of imaginative activity and a strong need for repetition (Turner, 1999). One of the cognitive activities that make up EF is generativity, which is to produce novel ideas and responses, often-examined using verbal fluency (VF) tasks (Pastor-Cerezuela et al., 2016). EF are widely researched for autistic people (Craig et al., 2016; Demetriou et al., 2018; Gilotty et al., 2002; Hill, 2004; Johnston et al., 2019; Luna et al., 2007; Ozonoff, 1997; Ozonoff & McEvoy, 1994), however, verbal fluency is a less common area. Even though research of verbal fluency in ASD has mostly focused on high functioning autism (HFA) or Asperger syndrome (Borkowska, 2015; Carmo et al., 2015; Corbett et al., 2009; Inokuchi & Kamio, 2013; Kenworthy et al., 2009; Spek et al., 2009), the studies reported contradicting results. The mentioned studies either found significant impairment in both semantic and phonemic tasks (Corbett et al., 2009; Czermainski et al., 2014; Kenworthy et al., 2009; Kleinhans et al., 2005), or similar performance (Borkowska, 2015) to the neurotypical group (NTP) but the use of different brain structures or compensatory methods (Baxter et al., 2019; Becher et al., 2012). Similarly, different results can be found for clustering and switching: Begeer et al. (2014) found a similar total number of words with the ASD group producing longer but fewer clusters while Ehlen et al. (2020) observed, that the ASD group produced smaller clusters and also fewer words than the NTP group. On the other hand, up until the 2010s, researchers predominantly tested the verbal fluency of children with ASD (Begeer et al., 2014; Corbett et al., 2009; Czermainski et al., 2014; Kenworthy et al., 2009; Sauz on et al., 2004) while the scientific research of adults has been more common in the last few years (Baxter et al., 2019; Carmo et al., 2015; Ehlen et al., 2020; Kiep & Spek, 2017; Sauz on et al., 2004). On the assumption that measuring only the overall score in fluency tasks does not capture essential qualitative aspects of the performance research, Carmo et al. (2017) have also perceived verbal fluency as a function of time and observed performance across time intervals. They found that the ASD group generated fewer words compared to the control group in the first 30 seconds (later in the first 15 s) due to a probable initiation deficit. To unravel the inconsistencies in recent research regarding the verbal fluency in ASD and to be able to study the qualitative, and more social aspects of language use, we aimed to measure potential deficits, atypicalities of quantitative, formal aspects of the verbal performance as well. In our study, we aimed to use a more comprehensive approach to assess the verbal fluency of people with ASD thus opening up new ways to understand not just the quantitative but the qualitative values of verbal fluency performance reintroducing the concept of Paivio et al. (1968): word concreteness and imageability.

Traditionally fluency tasks are built to test the ability to generate and produce novel ideas from a single stimulus or cue (Turner, 1999). Consequently, fluency tests can

be seen as a classic measurement of executive functions (Kav  et al., 2011; Kemper & Mcdowd, 2008; Koren et al., 2005). When exploring the EF of autistic people, research so far primarily focused on general quantitative performance or structural observations such as the number of words that the participants produce (Spek et al., 2009; Turner, 1999), clustering (Begeer et al., 2014), or brain functioning (Becher et al., 2012; Begeer et al., 2014; Kenworthy et al., 2009). Our research brings a new angle measuring the primarily activated word types using the concept of word abstraction (Darley et al., 1959; Flesch, 1950; Newton, 1992) and imageability (Cortese & Schock, 2013; Giesbrecht, 2004; Swaab et al., 2002).

According to previous research, there is a general cognitive processing advantage for concrete words (words referring to specific objects, e.g., car) over abstract words (words that refer to general, complex concepts and ideas, e.g., freedom). They are not just retrieved but also recognized faster which has been tested with free and cued recall and paired-associate learning tasks (Paivio, 1971; West & Holcomb, 2000). The reason behind the concreteness effect is assumed to be that concrete word representations are somewhat richer than abstract word representations (Kousta et al., 2011). According to the context availability model, the richness can be found in the quantity, that is, concrete words are thought to have greater contextual associations in the semantic memory (West & Holcomb, 2000) thus have a single, abstract, amodal representation system (Sadoski et al., 1995). On the contrary, dual coding theory (Paivio, 1971) assumes that all words activate representations in a verbal semantic system, but concrete words activate image-based codes to a greater degree (Binder et al., 2005). That is, it is more likely that the word “chair” (concrete) will evoke a concrete mental representation much quicker than the word “freedom” (abstract). Schafer et al. (2013) found that words relatively flexible in their use, thus having widespread associations, were underrepresented in the vocabulary of children with ASD compared with control groups. This may promote the idea of a general cognitive processing advantage—being retrieved and recognized faster—for concrete words over abstract words in the case of autistic people compared to the control group (Paivio, 1971; Paivio et al., 1994). A notion which could potentially open up new research methods and perspectives thus providing more understanding in the future regarding the executive functions of people with ASD.

Consequently, we hypothesize that autistic people may primarily use and rely on concrete words that are supported by image-based codes (that is, evoking mental representations of the word easily). We also set out, following Carmo et al.’s (Carmo et al., 2015, 2017) footsteps, to observe not just the overall word numbers generated but the difference between the performance on the first and the Second 30 s of the semantic and phonemic fluency tasks.

The present study's main objective hence is to explore the differences between ASD and NTP groups in the production of novel responses using phonemic and semantic fluency tests. Our three main questions are (1) whether we can find a between-group difference (ASD and NTP groups) in word productivity, clustering, or errors and perseverations, (2) whether the participants with ASD produce more words with higher imageability and higher concreteness values and (3) whether the participants with ASD will have a decreased productivity within the initial 30 s of fluency tasks.

MATERIALS AND METHODS

Participants

Sixteen participants (12 male, 4 female) with ASD without intellectual disability or language impairment (individuals with high-functioning autism) from the outpatient unit of the Department of Psychiatry and Psychotherapy, Semmelweis University, and 16 neurotypical control participants matched by gender, age, and education level were recruited in our study from October 2019 to March 2020 (Table 1). All our participants were Hungarian citizens and their primarily used language was Hungarian. Participation in the study was voluntary, no incentives were offered. The study was conducted in accordance with the Declaration of Helsinki and it was approved by the Regional and Institutional Committee of Science and Research Ethics, Semmelweis University, Budapest, Hungary (SERKEB No.: 145/2019), and participants gave their written informed consent before the procedures. Informed consent was also obtained from a parent and/or legal guardian of participants with ASD when it was required. The experiment took place at the Laboratory of Brain, Memory and Language Lab, Eötvös Loránd University, Budapest.

Task and procedure

We used phonemic and semantic fluency tests to assess the participants. In these tests, participants were asked to sit down in front of the assistant as close as they would hear them comfortably. After taking a seat, starting with the letter (phonemic) fluency task, they were given the instructions as well as an example of three possible correct answers starting with the sound "L". During the test, they were given 1 min to list as many words as they could on phonemic (sound "T," sound "K") and semantic category ("animals" and "groceries") conditions. Audio recordings were made of the tests and later transcribed. Once all the errors and perseverations were ruled out, we created a list of all the words acquired (ASD and NTP mixed). The total number of words was calculated by subtracting the total number of errors and perseverations

of the number of words acquired (da Silva et al., 2004; Tánczos, Janacsek, & Nemeth, 2014; Tánczos, Janacsek, & Németh, 2014; Tröster et al., 1998; Troyer et al., 1998). Perseverations were words that have been used already by the same participant. We marked word variants as errors (e.g., "kiscica" translated as "little cat," "kiskutya" translated as "little dog," etc.) Using the same word with different suffixes was not marked as a mistake if a Hungarian suffix changed the meaning of the word, as it did not refer to the same concept. Words starting with the inappropriate sound, or not being an element of the given categories along with names were also excluded and marked as errors.

For the rating of concreteness and imageability, we used Paivio et al.'s (1968) seven-point scale to rate the words (669 words in total) for concreteness and imageability. We recruited 69 raters with snowball method through an online questionnaire. For the ratings, we used a custom-built form that would gather imageability and concreteness ratings of a subset of the word pool we were testing against, based on user input. That is, to keep rater motivation high, with each rater only 50 words were lifted from the word pool and were given one mark. Thus, with each new rater logged in, only 50 of the lowest marked words were pulled from the pool so that all words would have an equal chance to be rated. Using 69 raters the whole word pool was rated five times. The instructions of the raters, as per Paivio et al. (1968), were the following:

¹*For imageability:* Any word which, in your estimation, arouses a mental image (i.e., a mental picture, or sound, or other sensory experience) very quickly and easily should be given a high imagery rating; any word that arouses a mental image with difficulty or not at all, should be given a low imagery rating. Think of the words "apple" or "fact." "Apple" would probably arouse an image relatively easily and would be rated as high imagery; "fact" would probably do so with difficulty and would be rated as low imagery. Since words tend to make you think of other words as associates, you must note only the ease of getting a mental image of an object or an event to the word itself, not the associations.

For measuring concreteness, we used the scale from Spreen and Schulz (1966) as cited in Paivio et al. (1968). We used low and high concreteness instead of concreteness and abstractness, as due to the structure of the form used, it was not possible to label the endpoints. The instructions for concreteness were the following:

¹Please note that all the instructions were written in Hungarian thus the Hungarian translation might differ slightly.

TABLE 1 Participant characteristics

N (male, female)	ASD		NTP		Statistics	
	16 (12, 4)		16 (12, 4)		$\chi^2 = 0$	
	Mean (min, max)	SD	Mean (min, max)	SD	Mann–Whitney (W)	<i>p</i>
Age (years)	27.000 (19, 44)	7.099	25.625 (19, 43)	6.752	99.000	0.280
Education (years)	15.875 (12, 21)	3.047	16.188 (12, 23)	3.633	132.500	0.879
AQ	30.188 (15, 41)	7.083	15.500 (5, 27)	6.208	16.000	<0.001
MZQ	51.000 (31, 67)	11.069	38.063 (22, 62)	10.497	52.000	0.004
AAS anxious	22.313 (13, 30)	6.570	16.000 (7, 30)	6.573	66.000	0.020
Avoidant	41.500 (24, 52)	7.975	32.438 (20, 51)	8.148	52.500	0.005
ASRS A	13.250 (2, 19)	3.992	10.063 (4, 17)	4.041	70.000	0.029
B	26.063 (9, 42)	10.036	16.375 (8, 29)	6.407	57.000	0.008
STAI-T	56.938 (36, 71)	11.997	45.438 (31, 62)	9.716	58.000	0.009
ADI-R (A + B + C)	34.250 (20, 47)	7.443	-	-	-	-
ADOS (A + B)	10.000 (5, 18)	3.847	-	-	-	-
WCST	12.359 (0, 39.84)	8.868	12.557 (6.25, 21.09)	3.982	114.000	0.444
Go/no go 1	0.527 (0.16, 0.84)	0.186	0.591 (0.34, 0.90)	0.173	110.500	0.363
Go/no go 2	0.952 (0.84, 1.00)	0.042	0.987 (0.95, 1.00)	0.015	53.500	0.002
DSPAN	6.88 (2, 10)	1.576	7.130 (6, 8)	0.806	124.000	0.683
CSPAN	3.686 (2.33, 5.66)	0.924	3.917 (2.3, 5.67)	0.985	114.000	0.444

Abbreviations: AAS, adult attachment scale; ADI-R (A + B + C), autism diagnostic interview-revised (sum of subscales A: reciprocal social interaction, B: communication and language, C: repetitive, stereotyped behaviors); ADOS (A + B), autism diagnostic observation schedule IV- modul (sum of subscales A: Communication, B: Reciprocal Social Interaction); AQ, autism-spectrum quotient; ASD, autism spectrum disorder; ASRS, adult ADHD self-report scale; CSPAN, counting span test; DSPAN digit span test; Go/no go 1, go/no go task, where participants reacted to the more frequent stimulus (correct answers/false alarm); Go/no go 2, go/no go task, where participants reacted to the less frequent stimulus (correct answer/false alarm); MZQ, mentalization questionnaire; N, number of participants; NTP, neurotypical healthy control; SD, standard deviations; STAI-T, state–trait anxiety inventory-trait; WCST, Wisconsin card sorting test (percentage of perseverative errors).

For concreteness: Any word, that in your estimation refers to concrete objects, materials or people, should get a high concreteness rating, any word that refers to an abstract concept and does not have a concrete reference, should get a low concreteness rating. If you think of the words “chair” and “freedom” while “chair” has a concrete object that it refers to, “freedom” will only activate associations and does not have a concrete reference thus should receive low concreteness rating.

Examples of words with high concreteness and imageability values included “kakas”/“rooster” (7.00 concreteness, 6.83 imageability) and “kalap”/“hat” (7.00 concreteness, 6.78 imageability) while words low on these scales included “kétely”/“doubt” (1.95 concreteness, 2.76 imageability) and “talán”/“maybe” (1.33 concreteness, 2.72 imageability).

For the category clustering of the words, we first excluded the errors and perseverations and then started the coding of the clusters. We used the study of Tánzos, Janacsek, and Németh’s (2014); Tánzos, Janacsek, and Németh’s (2014) as guidance. In case of overlap in the categories, we counted it as a new cluster. Words without clusters (only one individual word) got the code “1” while

all the other clusters got the code of the total number of words in them. The number of clusters was calculated by adding all the clusters together that had a code higher than 1. The number of switching was calculated by cluster numbers plus individual words minus one. We also calculated an average cluster size and distribution. (For terminology descriptions see Data S1).

Statistical analysis

Firstly, we calculated the average word counts for both fluency types. To test the interaction of fluency types and ASD, we ran a mixed-design analysis of variance (ANOVA), where we added our two groups as between-subject variable (ASD/NTP) and fluency type average as a within-subject variable (semantic average/phonemic average). To observe the between-group tendencies in the number of clusters we used Mann–Whitney test while we used *t* test to observe the mean-cluster size. To test if errors and perseverations were significantly higher in the ASD group, we calculated the average number of errors and perseverations for each participant and after checking the normality we used Mann–Whitney test.

To explore if the ASD group produced more concrete words, imageability and concreteness scores of all the given answers on the phonemic fluency test were

averaged across all the raters and matched with the appropriate participant's answer. We did not include the words from the semantic fluency test since the category itself determines the concreteness of the words thus giving the category "animals" would subsequently only produce words with high concreteness ratings. Averaged concreteness and imageability values then were calculated for all participants based on every correct answer they gave on the category fluency conditions. We ran Kendall's tau correlation to test the association between those two scales. We used Shapiro–Wilk test and Levene's test to test normality and equality of variances (respectively) where needed. We defined high imageability words as those that received scores 6 or more after Paivio et al. (1968) while also extending their method by adding low imageability words defined as receiving scores of 2 or less. We calculated the sum of words within these ranges for each subject. We used independent-sample *t* test where normality was assumed and Mann–Whitney test where it was not. In both cases, the independent variable was the two groups (ASD/NTP) while the dependent variable was the word count.

Analyses and visualization were performed with R (R Core Team, 2020) and the R-packages *readxl* (Wickham et al., 2019), *tidyverse* (Wickham et al., 2019), and *ggpubr* (Kassambara, 2020).

RESULTS

Is there a difference between the ASD and NTP groups in the average word count, clustering, errors, and perseverations?

To assess the difference between the groups in average word count we used ANOVA. We found fluency type main effect significant ($F[1,30] = 61.082, p < 0.001, \eta^2_p = 0.671$), which was due to the higher average number of words on the semantic condition (see Figure 1). That is, for both groups more words were produced on the semantic than on the phonemic condition. Fluency type \times group effect ($F[1,30] = 0.052, p = 0.822, \eta^2_p = 0.002$) and group main effect ($F[1, 30] = 0.207, p = 0.652, \eta^2_p = 0.007$), however, was not significant. Consequently, even though the participants generally produced more words on the semantic tests, we did not find differences between the two groups. We also did not find a significant between-group difference in the number of clusters ($U = 127.00, p = 0.985, d' = 0.013, Md_{ASD} = 17.000; Md_{NTP} = 16.000$). We did not find significant difference between ASD ($M = 2.768, SD = 0.592$), and NTP ($M = 2.671, SD = .632$) in mean cluster size either ($t[30] = -0.448, p = 0.657, d' = 0.158$). For the average number of errors ($U = 120.000, p = 0.780, d' = 0.107, Md_{ASD} = 0.000; Md_{NTP} = 0.000$; at least half of the participants did not make any error) and perseverations ($U = 158.500, p = 0.254, d' = 0.415,$

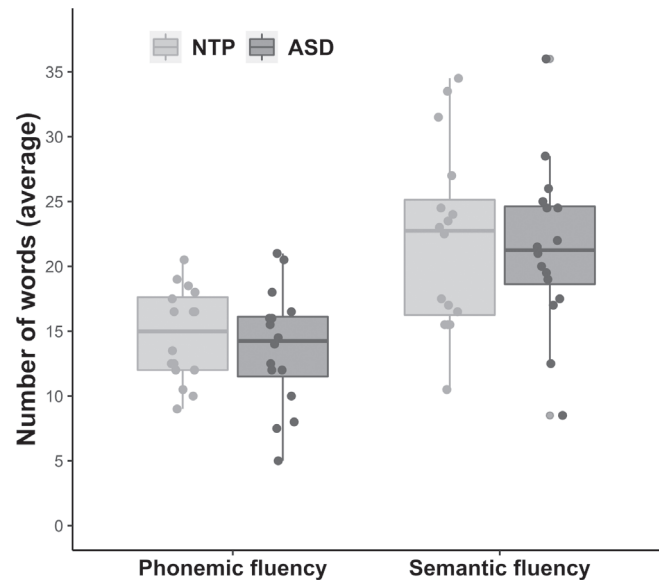


FIGURE 1 Average number of words produced by ASD and NTP groups for phonemic and semantic fluency tasks. The top and the bottom of the box show the upper (Q3) and lower (Q1) quartiles, the line dividing the box represents the median, and notches show a 95% confidence interval around the median

$Md_{ASD} = 0.250; Md_{NTP} = 0.000$) on phonemic and semantic fluency tests for ASD and NTP groups we found no significant difference.

Did the ASD group produce more words with higher imageability and lower concreteness values?

Independent-sample *t* test did not show significant difference between the ASD and the NTP groups for high imageability ($t[30] = 0.367, p = 0.716, d' = 0.130$), high concreteness ($t[30] = -0.549, p = 0.587, d' = -0.194$) and low concreteness word counts ($t[30] = 0.358, p = 0.723, d' = 0.127$) and according to the Mann–Whitney test we did not find significant difference between groups on low imageability word count either ($U = 122.500, p = 0.834, d' = 0.073$, see Figure 2). Subsequently, even though the ASD group produced slightly more concrete and imageable words than the NTP group, the difference between the two groups was not extensive enough to be significant. Despite the statistical benefits of treating a variable as continuous (as opposed to categorical), we decided to analyze our data this way to replicate Paivio et al. (1968). Nevertheless, we ran the analysis using imageability and concreteness as continuous variables. This change did not result in different outcome: we did not find any significant differences between the group means of imageability ($t[30] = -1.096, p = 0.282, d = -0.387$), or concreteness ($t[30] = -0.928, p = 0.361, d = -0.328$), see Figure S1.

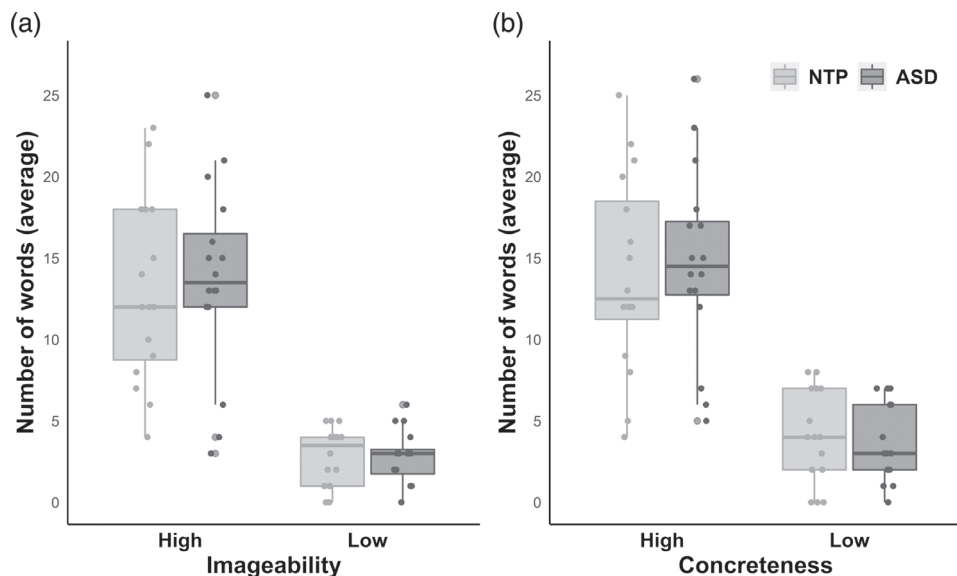


FIGURE 2 Average number of words produced by ASD and NTP groups getting high (6 or above) or low (2 or below) imageability (panel a) and concreteness (panel b) scores. The top and the bottom of the box show the upper (Q3) and lower (Q1) quartiles, the line dividing the box represents the median, and notches show 95% confidence interval around the median

Did the ASD group have a decreased productivity within the initial 30 s of fluency tasks?

To assess the differences between the first and the second 30 s of the fluency tasks we used ANOVA (Figure 3). We observed and tested the time sections for concreteness and imageability (high, low, average) values as well (Figure 4). We could not find significant group \times time effect either in the high imageability word count ($F[1, 30] = 0.496, p = 0.487, \eta^2_p = 0.016$), low imageability word count ($F[1, 30] = 0.254, p = 0.618, \eta^2_p = 0.008$), average imageability ($F[1, 30] = 1.242, p = 0.274, \eta^2_p = 0.040$) or high concreteness word count ($F[1, 30] < 0.001, p = 1.000, \eta^2_p < 0.001$), low concreteness word count ($F[1, 30] = 1.357, p = 0.253, \eta^2_p = 0.043$) or average concreteness ($F[1, 30] = 0.732, p = 0.399, \eta^2_p = 0.024$) values. That is, we found no significant difference between the NTP and the ASD groups in the concreteness and imageability values and the average word count in the first and the second 30 s of the fluency test.

DISCUSSION

In this study, we aimed to explore the imageability and the concreteness values of the words produced by people with ASD compared with neurotypical subjects. We hypothesized that the ASD groups may lag behind the NTP group in word count, clustering, switching, and the abstractness of the words produced, however, our results did not show any significant between-group difference even when observing and comparing the first and the second 30 s of the test.

We expected the total number of words produced on phonemic and semantic fluency tests to show between-group interaction; however, we did not find significant

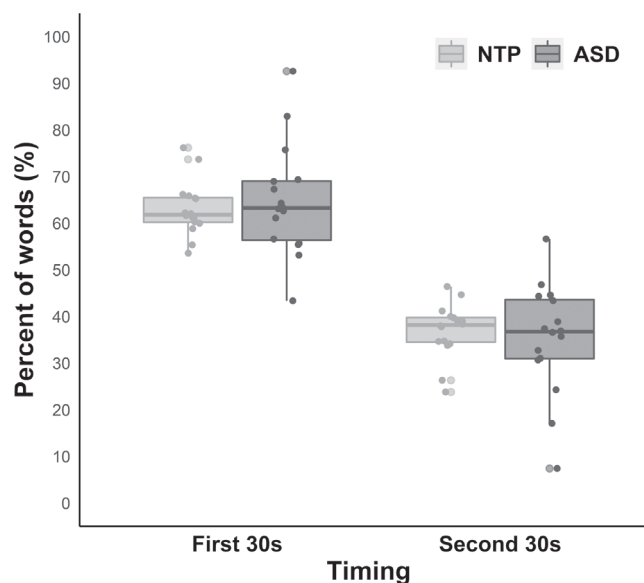
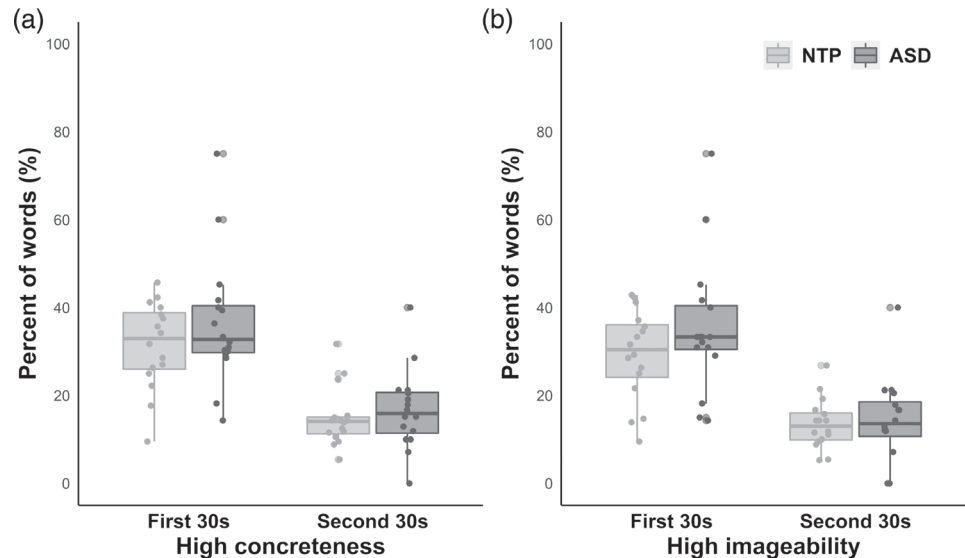


FIGURE 3 Proportion of words produced by ASD and NTP groups during the first and second parts of the task. The top and the bottom of the box show the upper (Q3) and lower (Q1) quartiles, the line dividing the box represents the median, and notches show 95% confidence interval around the median

differences between the ASD and the NTP groups. This result is in line with Borkowska (2015) and Beacher et al. (2012) finding equivalent task performance and no general deficit in their verbal fluency. What's more, Borkowska (2015) also found no difference in perseverations that is also in line with our study. Inokuchi and Kamio (2013) could not discriminate subjects with ASD from the NTP group either based on the letter fluency task while the ASD group performed poorly on the category fluency task. However, we can also find contradicting evidence from Spek et al. (2009), who detected significant impairment in both fluency tasks. We, on the

FIGURE 4 Proportion of words produced by ASD and NTP groups getting high (6 or above) concreteness (panel a) and imageability (panel b) scores during the first and second part of the task. The top and the bottom of the box show the upper (Q3) and lower (Q1) quartiles, the line dividing the box represents the median, and notches show 95% confidence interval around the median



other hand, did not find significant between-group differences in either of the two types of fluency. This result might point toward the possibility of intact fluency in autism, however, as discussed later, further studies are required to be able to support that theory. We also expected the total number of errors and perseverations to be higher for the ASD group, yet, did not find a significant difference between the neurotypical and autistic participants that contradicts the research results of Turner (1999) and Lopez et al. (2005). Regarding perseverations and errors, however, our results were in line with Borkowska (2015) who found that the ASD group's performance showed no perseverations, and comparably frequent clustering and switching. These results are interesting because in our study the two matched study groups did not differ significantly in other cognitive functions either (except inhibition), but they did in terms of variables characteristic of ASD. That is, in this selected sample, no difference could be detected at this quantitative level of the verbal fluency task.

In our second hypothesis, we predicted that the ASD group would produce fewer words rated low on the concreteness and imageability scales during the phonemic fluency tests than the control group. Even though previous research has already shown a general cognitive processing advantage (being recognized and retrieved faster) for concrete words over abstract words for neurotypical subjects (Paivio, 1971; Paivio et al., 1994), we hypothesized that ASD participants might activate concrete words to an even greater degree. We suspected this based on the results of Schafer et al. (2013) who examined comprehension and production vocabulary with the help of the Colorado meaningfulness (CM) test in typically developing children and those with ASD and Down syndrome. They found that words high on CM, that is, being relatively flexible in their use including more intensive use of context, thus having wide-spread associations, were underrepresented in the

vocabulary of ASD children compared with both control groups. Consequently, words high on CM in our study meant words lower on the concreteness and imageability scales (for example the word “have to” or the word “maybe”) as they do not evoke a concrete visual representation quickly but instead would recall many associations. Our suspicion, however, has not been confirmed and our results showed that both groups (ASD and NTP) produced more words that are high on concreteness and imageability, but they did not differ significantly. That is, we suggest that people with autism can recall words evoking concrete mental representations to a similar degree as neurotypical people. However, we must mention that phonemic fluency tests might not be sensitive enough to give an accurate depiction of the whole spectrum of recalled words in everyday language use.

We were also curious about the differences that we might find in the total average word count and the high and low imageability and concreteness values between the first and the second 30-second intervals. We relied on the studies of Carmo (Carmo et al., 2015, 2017) who found impaired performance in the ASD group in the first 30 s and interpreted these results to be preliminary findings of deficits on their initiation process. We, however, did not find significant differences between the ASD and the NTP groups, that is, the ASD group as well as the NTP group produced more words in the first 30 s and much less in the second 30 s, but the two groups did not differ significantly.

The results above, thus, point us to the idea that ASD participants without intellectual disability and language impairment may inherently perform just as well in a fluency test as NTP participants or otherwise be using compensatory mechanisms. Regarding which we also have to consider the possibility that a certain subset of the people with ASD group mobilizes different brain networks and behavioral elements to compensate, a proposal of which

was underlined by the recent neuroimaging studies of Baxter et al. (2019) and Beacher et al. (2012). Furthermore, this result might lead to the questioning of a verbal fluency initiation deficit for autistic participants without intellectual disability or language impairment. A proposal, which we suggest, still has to be underlined by future research.

Among the limitations of the current study, we can mention the fact that due to the restrictions of the COVID-19 pandemic we could only involve 16 neurotypical and 16 autistic people and had to stop the project. As for the tests themselves, we observed that the ASD group have said more words that were rare or not part of the everyday language (e.g., the word “tympanum” or “pangolin”) that subsequently received lower imageability and concreteness points as our raters supposedly did not know that particular word. To eliminate that distortion in a future study we propose to ask participants to rate their own words to be able to observe the between-group rating patterns. We would also suggest a complimentary analysis of speech graphs to be able to demonstrate possible alterations of the thought process manifested in the speech (Mota et al., 2012).

We can also mention the homogeneity of the subjects as a limitation, that is, in our study, we did not examine people with autism from the whole spectrum, rather a limited sample matched with neurotypical controls by as many factors as possible (see Table 1). Thus, the differences between that subset and neurotypical people are prone to be less prominent, highlighting the importance of working with participants from the entire spectrum. Apart from this, another language-based test is suggested to be used in the future. Graph analysis of verbal fluency tests (Bertola et al., 2014) as well as the graph analysis of free flow speech and later self-rating using concreteness and imageability is supported. This method may be suitable for better portraying the differences not just between NTP and ASD subjects but also between the people on different points of the spectrum.

For future directions, we also promote research of the connection between word prototypicality and concreteness values. Uyeda and Mandler (1980) in their study used a six-point scale to measure the prototypicality of the produced words. The mentioned study serves as an outstanding starting point for a future study where possible similarities or differences between prototypicality and concreteness scales could be explored. We also suggest measuring vocabulary breadth and depth, the latest being an excellent approach to measure the semantic, pragmatic knowledge, or the understanding the decontextualized meaning of words (e.g., meaning in different affective context, sarcasm), that are more often impaired in ASD. We argue that qualitative measurement of verbal expression is essential to understand the nature of communication atypicalities in ASD, and quantitative aspects of verbal fluency might be considered as a control task in future studies.

CONCLUSION

In our study, we applied a comprehensive approach to measure verbal fluency performance. Participants with ASD showed intact performance in the total number of answers, the number of errors, and perseveration in either semantic or phonetic fluency subtasks. We found similar performance between the NTP and ASD groups in the time dynamics of fluency after comparing the first and second 30 s intervals. We also introduced a new approach by measuring the imageability and concreteness characteristics of the answers, first in autism research. Based on these new indices, we also showed comparable fluency between the two study groups. Previous studies and our results together shed light on the complexity of fluency in autism. We emphasize that such a comprehensive approach is necessary for future research and diagnostics to understand and use fluency tasks in autism and other neurodevelopmental disorders.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

Odett Tóth, Orsolya Pesthy, Kinga Farkas, Dezső Németh contributed to the design and implementation of the research, developed the theoretical formalism. Odett Tóth, Orsolya Pesthy, Kinga Farkas performed the computations. Kinga Farkas designed the figures. Odett Tóth, Orsolya Pesthy, Kinga Farkas, Dezső Németh wrote the manuscript. Orsolya Pesthy and Anna Guttengéber carried out the experiment. Bálint Szuromi and Eszter Komoróczy contributed to sample preparation. Dezső Németh and János M. Réthelyi supervised the project. All authors provided critical feedback and helped shape the research, analysis, and manuscript.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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