

(Central) Auditory Processing Skills in Young Adults with Autism Spectrum Disorder

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Abstract

Many studies have shown differences in the way individuals with Autism Spectrum Disorder (ASD) process auditory information when compared to typically developing peers. These include differences in sensitivity to sounds, in electrophysiological responding, and in responding to behavioral tasks that utilize (Central) Auditory Processing ((C)AP) skills. The current study aimed to expand this literature by examining the relationship between ASD and (C)AP across all six associated skills (i.e., localization/lateralization, discrimination, pattern recognition, temporal aspects, performance with competing signals, and performance with degraded signals). The purpose was to determine 1) patterns of responding among a group of individuals with ASD for subtests that address the (C)AP skill areas and 2) the association between (C)AP subtest and composite scores for a group of individuals with ASD and a group of typically developing peers.

To achieve this purpose, seven participants between 18 and 21 years of age with ASD and seven age- and gender-matched control participants completed a case history, passed a hearing screening, and participated in assessments measuring (C)AP skills. A Multivariate Analysis of Variance (MANOVA) was used to assess between group differences.

Descriptively, patterns of responding were identified for the ASD group, with lower scores in subtests that required dichotic listening. Heterogeneity in responding was also evident. Statistical analysis revealed significant between-group differences for only one subtest, *SCAN-3:A Competing Words-Free Recall* ($F(1,13)=5.21, p<.05$). No significant results were identified for other (C)AP subtests or for the composite score.

These results extend past research and support findings that suggest some differences in the way individuals with ASD process auditory information compared to typically developing peers. Results warrant further research with a larger sample size, as well as research that addresses the clinical utility of (C)AP testing for individuals with ASD.

Keywords: (Central) auditory processing; Autism spectrum disorder; Dichotic listening

Introduction

According to Centers for Disease Control and Prevention, approximately 1 in 68 U.S. children have Autism Spectrum Disorder (ASD) [1]. This category of disorder, defined by impairments in social communication and interaction and restricted/repetitive behaviors/interests, has received attention from researchers as they seek to understand the relationship between a cause and behavioral symptoms displayed [2]. Some symptoms that occur in many individuals with ASD appear to have a close connection to hearing, including unresponsiveness to some auditory stimuli, hypersensitivity to certain noises, and difficulty understanding prosodic elements of speech [1]. Accordingly, a significant amount of research has been devoted to understanding the relationship between audition and ASD.

Studies relating to audition and ASD range from assessing peripheral hearing abilities to skills that are associated with (Central) Auditory Processing ((C)AP), defined as “the efficiency and effectiveness by which the Central Nervous System (CNS) utilizes auditory information” [3]. Relevant research findings suggest: 1) there

may be a slightly higher rate of hearing loss in the ASD population than in individuals who are typically developing [4]; 2) significantly more individuals with ASD display hypersensitivity to sound and unusual auditory interests/auditory sensory seeking than typically developing individuals [4-8]; and, 3) using electrophysiological testing, significant differences between groups of individuals with ASD and typically developing controls exist for components of Event Related Potentials (ERP), including the mismatch negativity (a response that reflects automatic neural reaction to changes in auditory stimulation) and P3a potentials (a response that requires conscious attention to changes in stimulation) depending on type of stimuli used [9-17].

In addition, some research has focused on the relationship between (C)AP skills and ASD using behavioral measures. One study by Alcantara, Weisblatt, Moore, and Bolton [18] compared the ability to recognize speech in noise between a group of individuals with ASD and a group of control participants when listening to spoken sentences in the presence of various types of background noise that included temporal dips, spectral dips, and a combination of the two. The authors found significant differences between groups in their ability to recognize speech in noise when dips in timing were present. Groen and colleagues [19] also examined perception of speech in noise in a

group of individuals with ASD and a group of typically developing control participants. Using stimuli that controlled for effects of language, these researchers also found the group with ASD had significantly fewer gains in speech perception in noise with timing dips. A study by Bonnel and colleagues [20] examined the ability of individual's with ASD to discriminate simple and complex tones differing in pitch, vocal-timbre, non vocal-timbre, and loudness. The individuals with autism were significantly better at discriminating pitch than individuals in the Asperger and control groups.

While these studies have furthered our understanding of the relationship between ASD and audition, there continue to be questions left unanswered and further research is warranted on this matter. To date, no known studies have examined (C)AP skill abilities in individuals with ASD using tests design to identify (C)AP problems in the general population. Although there is some disagreement in the field, behavioral tests are considered the current standard of diagnosing (C)AP problems by many and are important for determining the examinees' strengths and limitations in each of the six skills areas associated with (C)AP [3]. These skill areas include 1) sound source localization and lateralization (determining the source of the auditory stimulus and location perceived by the listener), 2) auditory discrimination (differentiation of auditory stimuli), 3) auditory pattern recognition (sequencing stimuli), 4) temporal aspects of audition (perceiving features of time), 5) auditory performance in competing acoustic signals (hearing in noise), and 6) auditory performance with degraded acoustic signals (hearing when the signal is unclear) [21,22]. Therefore, the purpose of the current study was to determine 1) patterns of responding among a group of individuals with ASD for subtests that address the (C)AP skill areas, and 2) the association between (C)AP subtest and composite scores for a group of

individuals with ASD and a control group of typically developing peers. Based on previous research, we hypothesized that similar within group patterns of responding would be found, but that between-group patterns would diverge with individuals in the ASD group scoring significantly lower than their age- and gender-matched peers for some of the (C)AP skill areas of assessment.

Methods

Participants, settings, and materials

Participants in this study included seven young adults (ages 18-21) recruited from an on-campus high school transition program for individuals with ASD and seven typically developing participants who were matched for age and gender recruited from classes at a Midwestern university in 2012. Review of the educational records for individuals in the ASD group revealed that with the exception of one participant who had an outside diagnosis of Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS), which fits into the current category of ASD, all students were receiving special education services under the category of ASD and had a diagnosis of Asperger Syndrome made by a school psychologist, outside professional, or both at the time of the study.

Inclusion criteria for the ASD group included having an IQ of 80 or higher as measured by educational records. Criteria for the Control group included no history of learning disabilities, measured by self-report. Information on participants' age, gender, and IQ can be found in Table 1. Finally, normal results on a hearing screening were required for both groups.

Control Participant	Age	Gender	ASD Participant	Age	Gender	Diagnosis	IQ Test	IQ Score
1	18	M	1	19	F	Asperger syndrome	WJ-III	124
2	18	M	2	19	M	Asperger syndrome	WJ-III	105
3	20	F	3	19	M	Asperger syndrome	WISC-IV	88
4	21	M	4	19	M	PDD-NOS	WAIS-IV	92
5	21	M	5	20	M	Asperger syndrome	WISC-IV	82*
6	21	M	6	21	M	Asperger syndrome	WAIS-IV	112
7	21	M	7	21	M	Asperger syndrome	WJ-III	94

Table 1: Age, Gender, Diagnoses, SCQ Scores, and IQ Information for Participants.*Three previous IQ tests ranged from 93 to 107; WAIS-IV: Wechsler Adult Intelligence Scale-Fourth Edition [23]; WJ-III: Woodcock-Johnson III Tests of Cognitive Abilities [24]; WISC-IV: *Wechsler Intelligence Scale for Children—Fourth Edition* [25].

Measures

The two (C)AP tests that were administered included the *SCAN-3:A for Adolescents and Adults, Tests of Auditory Processing Disorders* (SCAN-3:A) [26] and the *Differential Screening Test for Processing Measures* (DSTP) [27]. The *SCAN-3:A* is a test used to identify deficits in (C)AP skill areas in adolescents and adults. The *DSTP* is a test used to screen for deficits in three areas of neurological involvement relating to auditory stimuli. The subsets that target the perception of the "primary acoustic characteristics of an auditory signal" [27] were the only ones used during this study. Both tests were

administered in a sound treated booth using one of two calibrated two-channel audiometers and CD recording in a university Speech-Language and Hearing Clinic. The stimuli were presented in both ears at 50 dB HL.

The following gives a brief explanation of each subtest administered and indicates which subtests provide a measure of each (C)AP skill area. During the *SCAN-3:AAuditory-Figure Ground 0 dB* subtest, each participant heard words presented in background noise presented one at a time at the same intensity as the speaker and was asked to repeat each word back to the examiner; this subtest examined sound

localization/lateralization [26]. In the *DSTP Auditory Discrimination* subtest, each participant was asked to repeat nonsense syllables heard in background noise; this subtest examined auditory discrimination abilities [27]. The *DSTP Temporal Patterning* subtest addressed auditory pattern recognition/temporal ordering as participants heard three-tone sequences and were asked to imitate the sequence or indicate the order by saying “high” or “low” for each sound [27]. The *SCAN-3:A Gap Detection* subtest addressed temporal processing by asking the participant to indicate whether silence was detected between two tones by saying the number of tones heard, either “one” or “two” [26]. The *DSTP Dichotic Digits*, *SCAN-3:A Competing Words-Directed Ear*, *SCAN-3:A Competing Words-Free Recall*, and *SCAN-3:A Competing Sentences* subtests addressed performance with a competing signal. Participants listened to two stimuli presented simultaneously in different ears and then were asked to repeat 4 numbers heard (2 in each ear) back in any order for dichotic digit testing, to repeat back monosyllabic words in a specific order (i.e., word from the right ear and then the left ear or from the left ear and then the right ear) for competing words-directed ear tasks, to repeat monosyllabic words in any order for competing words-free recall, and to repeat back a sentence heard in previously identified ear (i.e., only the right ear or only the left ear) for competing sentence tasks [26,27]. In the *SCAN-3:A Filtered Words* and *SCAN-3:A Time Compressed Speech* subtests, the participants were asked to repeat back words that were low-pass filtered at 750 Hz and to repeat back a sentence that had been time compressed at 60%, respectively; these were used as measures for performance with a degraded signal [26]. The auditory processing composite score provided information on (C)AP skills and was calculated by adding subtests of the *SCAN-3A*.

Procedures

Following approval from the Institutional Review Board, informed consent explaining parameters of the study and optional participation was collected for all participants. With the exception of one participant whose parents also signed informed consent, participants were all considered their own legal guardians. Auditory testing was completed during an hour-long session that included a short hearing history completed in an interview format with the participant, otoscopy, tympanometry, and pure tone testing. Following a passed screening, a written statement was read by the clinician explaining what to expect during (C)AP testing. The *SCAN-3:A* and first three subtests of the *DSTP* were then administered in a counter balanced order so that both groups received both tests in the first and second positions an equal number of times. A short break, lasting less than 5-minutes, was offered after every two subtests to make the participants more comfortable. All measures were administered by trained speech-language pathology graduate students under the supervision of an ASHA certified audiologist or speech-language pathologist. At the end of the study, each participant received a report explaining the testing

that was conducted, the results, and interpretation of the results. If a participant scored low in any of the areas tested, suggestions were made for an appropriate next step and he or she was invited to come back to the clinic to discuss contents of the report.

Inter-observer agreement

Inter-observer agreement was collected by the primary investigator and 4 trained graduate clinicians for 5 of the 14 participants, or 35.71% of the (C)AP tests. Item-by-item agreement was calculated by taking the number of agreements divided by the number of agreements plus the number of disagreements. Mean overall agreement was 98.17% (with a range of 97.51% to 98.89% for participants and a range of 94.44% to 100% by subtest). These scores indicate excellent agreement on scoring among raters.

Statistical measures

Group membership (i.e., ASD versus Control) was the independent variable in this study. Dependent variables included scores on the various subtests of the *SCAN-3:A* and *DSTP* and the *Auditory Processing Composite* score on the *SCAN-3:A*. Predictive Analytics Software (PASW) was used for statistical analysis.

Data from the study was expressed through descriptive measures, including analysis of mean, standard deviation, and range of scores from individuals in the Control and ASD groups for all subtests of the *SCAN-3A* and *DSTP* and for the *SCAN-3A Composite* score. Descriptive data on normal, borderline, disorders, and failed subtest and composite scores were also provided for each participant and comparisons were made between groups. Statistical analysis for determining the association between test scores for a group of individuals with ASD and a control group included the use of a MANOVA, determining if the independent variable had significant effects on the dependent variables and examining interaction effects between dependent variables.

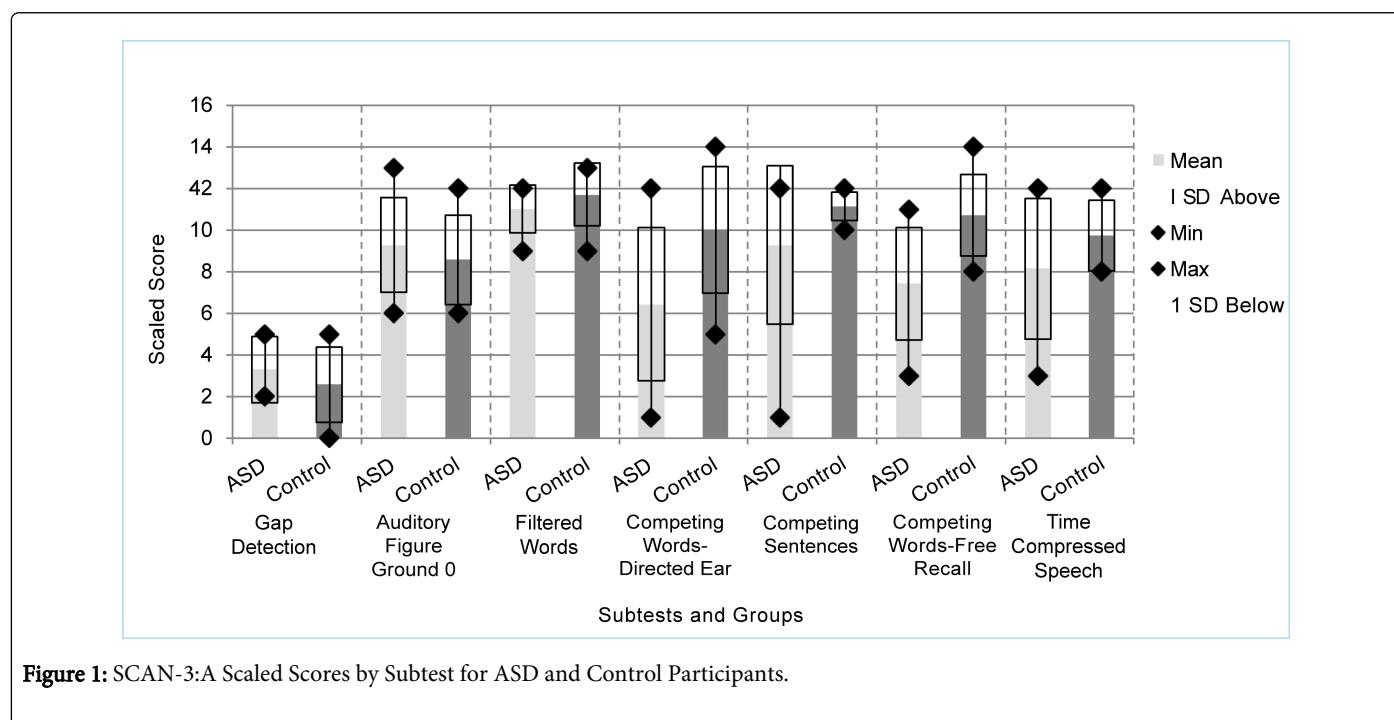
Results

Descriptive analysis was used to address the study’s first defined purpose, determining patterns of responding among a group of individuals with ASD for subtests that address the (C)AP skill areas. In general, the range of scores was wider indicating within group variability. In addition, the mean and median were lower on most subtests of the *SCAN-3:A* and *DSTP* for the participants with ASD. Mean, standard deviation, and ranges are given for both groups in Table 2 for subtests of the *SCAN-3:A*, *DSTP*, and *SCAN-3:A Composite* scores. Minimum/maximum scores (range), mean, one standard deviation above the mean, and one standard deviation below the mean are represented in Figure 1-3.

Subtest/Composite	Control Mean (SD)	Control Range	ASD Mean Scaled Score(SD)	ASD Range
Gap Detection	2.57 (1.81)	5	3.27 (1.60)	3
Auditory Figure Ground 0 dB	8.57 (2.15)	6	9.29 (2.29)	7
Filtered Words	11.71 (1.50)	4	11.00 (1.15)	3
Competing Words-Directed Ear	10.00 (3.06)	9	6.43 (3.69)	11

Competing Sentences	11.14 (0.70)	2	9.29 (3.82)	11
Competing Words-Free Recall	10.71 (1.98)	6	7.43 (2.70)	8
Time Compressed Speech	9.71 (1.70)	4	8.14 (3.39)	9
Dichotic Digits	11.71 (0.49)	1	11.29 (1.11)	3
Temporal Patterning	11.86 (0.38)	1	11.14 (2.27)	6
Auditory Discrimination	14.57 (1.72)	5	14.47 (1.81)	5
SCAN-3 Composite Score	101.86 (10.73)	34	92.29 (14.29)	44

Table 2: Descriptive Statistics for Control and ASD Groups on the SCAN-3 and DSTP.



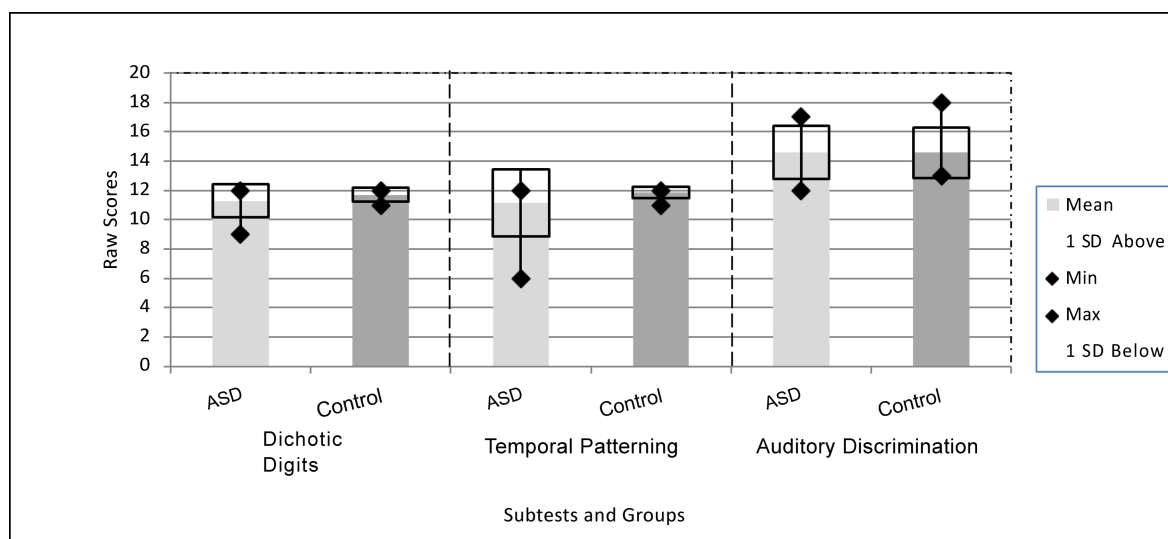


Figure 2: DSTP Raw Scores by Subtest for ASD and Control Participants.

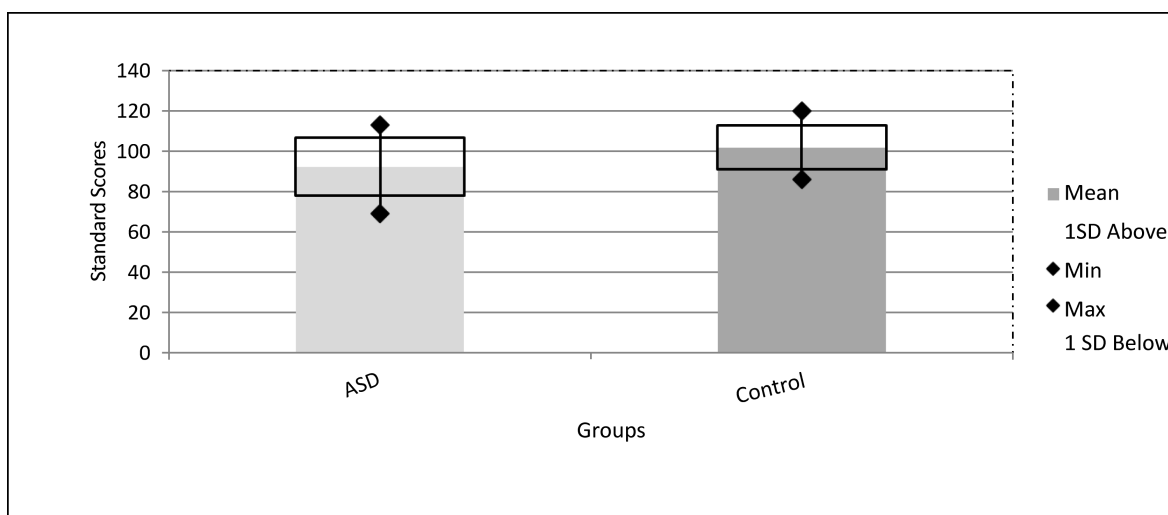


Figure 3: SCAN-3:A Composite Score for ASD and Control Participants.

For the subtests of *SCAN-3:A*, scaled and standard scores were used to determine if participants' results were in the normal, borderline, or disorder range. *DSTP* raw scores were used to determine if students met the cutoff for passing the subtest. More participants in the group of individuals with ASD scored in the borderline/disordered ranges

and failed screenings than those in the group of Control individuals. *Competing Words-Directed Ear* and *Competing Words-Free Recall* had the most participants with ASD score in the borderline or disordered range (Table 3).

Participant Group	ASD	SCAN-3:A GD	SCAN-3:A AFG 0	SCAN-3:A FW	SCAN-3:A CW-DE	SCAN-3:A CS	SCAN-3:A CW-FR	SCAN-3:A TCS	SCAN Composite 3:A	DSTP DD	DSTP TP	DSTP AD
1		5	10	11	8	12	11	9	101	12	12	12*
2		2	8	11	9	12	8	12	99	12	12	16
3		2	9	12	6*	10	6*	12	93	11	12	14

4	5	6*	12	6*	11	8	7	90	11	12	17
5	5	8	10	3**	9	6*	3**	81*	12	6*	14
6	2	13	12	12	10	10	9	113	12	12	13*
7	2	11	9	1**	1**	3**	5*	69**	9*	12	16
Participant Control Group	SCAN-3:A GD	SCAN-3:A AFG 0	SCAN-3:A FW	SCAN-3:A CW-DE	SCAN-3:A CS	SCAN-3:A CW-FR	SCAN-3:A TCS	SCAN 3:A- Composite	DSTP DD	DSTP TP	DSTP AD
1	5	6**	11	11	11	11	8	97	12	12	14
2	2	7	11	5**	10	8	8	86	12	12	14
3	2	7	13	13	11	14	9	106	11	11**	15
4	2	12	13	14	11	12	9	120	12	12	18
5	5	10	13	10	12	11	12	108	12	12	15
6	2	10	9	9	11	9	10	97	12	12	13**
7	0	8	12	8	12	10	12	99	11	12	13**

Table 3: Normal, Borderline, Disordered, and Failed Tests on the SCAN-3:A and DSTP by Participant for ASD and Control Groups.*Borderline/Failed Screening; **Disordered; GD: Gap Detection; AFG 0: Auditory Figure Ground 0; FW: Filtered Words; CW-DE: Competing Words-Directed Ear; CS: Competing Sentences; CW-FR: Competing Words-Free Recall; TCS: Time Compressed Sentences; DD: Dichotic Digits; TP: Temporal Patterning; AD: Auditory Discrimination.

A MANOVA was used to address the study's second listed purpose, determining the association between (C)AP subtest and composite scores for a group of individuals with ASD and a control group of typically developing peers. No significant differences were found for the majority of the subtests on the *SCAN-3:A* or *DSTP* and no significant effect was found for the composite auditory processing score on the *SCAN-3:A*. These results indicate that group membership

did not predict the score for most (C)AP skills subtests or the *SCAN-3:A Auditory Processing Composite* score. There was one exception on the *SCAN-3:A Competing Words-Free Recall* subtest in which significant between-group differences were seen ($F(1,13)=5.21, p<.05$). These results indicate that individuals with ASD are more likely to score lower on this specific subtest (Table 4).

(C)AP Skill Area	Subtest/Composite	df	F	p
Sound Localization/Lateralization	SCAN-3:A Auditory Figure Ground 0**	13	0.12	0.74
Auditory Discrimination	DSTP Auditory Discrimination	13	0.06	0.82
Auditory Pattern Recognition	DSTP Temporal Patterning**	13	0.85	0.38
Temporal Processing	SCAN-3:A Gap Detection	13	0.92	0.36
Performance with a Competing Signal	DSTP Dichotic Digits**	13	0.03	0.87
Performance with a Competing Signal	SCAN-3:A Competing Words-Free Recall	13	5.21	0.04*
Performance with a Competing Signal	SCAN-3:A Competing Words-Directed Ear**	13	2.45	0.15
Performance with a Competing Signal	SCAN-3:A Competing Sentences**	13	0.79	0.39
Performance with a Degraded Signal	SCAN-3:A Filtered Words	13	0.31	0.59
Performance with a Degraded Signal	SCAN-3:A Time Compressed Speech	13	0.52	0.49
	SCAN-3:A Composite Score*	13	0.90	0.36

Table 4: MANOVA Results by Subtest/Composite.* $p<.05$; **Subtests designed to measure the same (C)AP skill area.

Discussion

Based on hypotheses made from previous research, results of the current study were mixed as 1) similar patterns of responding were found, but also some heterogeneity existed in responding within individuals in the ASD group, and 2) a significantly lower score was found for the group of individuals with ASD when compared with the Control group on the SCAN-3:A *Competing Words Free Recall* subtest, but for no other subtests of composite score. Therefore, the current study supports previous findings that both similarities and differences exist in the way individuals with ASD completed behavioral tasks that required use of (C)AP skill abilities when compared with typically developing peers [18-20].

The novel design of the current study, including assessment with behavioral tests designed to measure various (C)AP skill areas, allowed for discovery of original findings. Analysis with descriptive measures demonstrates that while ASD can likely be related to co-morbid (C)AP skills (especially performance with a competing signal), the disorder does not appear to affect skill area testing for all individuals with ASD. This elicits the question of whether there may be subgroups of ASD that have specific difficulty with (C)AP skills. This seems to be consistent with broader research suggesting that there are subcategories of ASD with structural, physiological, and behavioral symptom differences [28].

Another novel finding included identification of significant between group differences for only one of the subtests designed to measure auditory performance with a competing signal. Possible explanations include differences in task requirement (e.g., requiring divided attention rather than focused attention) and specific stimuli used (e.g., linguistic stimuli rather than rote numerical stimuli) [26]. Perhaps this relates to previous electrophysiological research finding attention or inattention to a task affects results of differences between groups of individual with ASD and typically developing peers for portions of the ERP [9-17]. Additionally, no other tests measuring (C)AP skill areas resulted in significant between group differences. These results may be related to underlying associated structural and physiologic components (e.g., dichotic listening abilities require the auditory signal to cross from the right to left hemisphere across the corpus callosum, which may be smaller in individuals with ASD [29]).

Before making any conclusive statements regarding (C)AP skills in young adults with ASD, limitations of the study must be addressed. One potential limitation was the small group sizes, potentially leading to Type I or II error. It is recommended that future research conduct a power analysis to determine a recommended sample size to obtain significant results. A second limitation of the study was the method for determining whether participants met the criteria for membership into the two groups (e.g., relying on chart review and self-report). Thus, it is possible that participants would not have met inclusion criteria into the different groups had more current and formal measures been used. A third limitation was the restricted number of variables that could be collected and analyzed for both the ASD and Control groups (such as comorbidity of other disorders and information on current medication). According to ASHA [5], these variables may have been a confounding variable of this study. In addition, 6 of the 7 participants in each group were male. While the majority of individuals with ASD are male [1], results from this study containing mostly male participants cannot necessarily be applied to individuals with ASD of both genders. Finally, some subtests of the *SCAN-3:A* and all of the *DSTP* subtests are considered screening measures for adults and children under 13, respectively [26,27]. Therefore, the specificity on

these tests is not as rigorous as diagnostic tests and no scaled or standard scores can be produced, leaving suboptimal data for statistical analysis.

Future research would benefit from addressing these limitations. Additional research should examine how results relate to individuals with different severity levels of ASD, as well as younger children with ASD so that, if applicable, the effects of early intervention can be maximized. Research that examines the relation between electrophysiological testing and behavior testing would also contribute to our understanding of (C)AP, ASD, and the association between the two.

Clinical implications of understanding (C)AP skills in individuals with ASD should also be examined in future research. While (C)AP tests cannot and should not be used to give individuals with ASD a diagnosis of (C)AP Disorder (because it is considered a "higher order disorder" and therefore cannot be assigned if the ASD diagnostic label has been given [3]), one potential implication may be whether assessment of (C)AP skills using behavioral tests and resulting interventions are beneficial for individuals with ASD. In the current study, membership in the ASD group did not predict performance for the composite (C)AP battery or for most of the (C)AP subtests. Therefore, assessment of individuals with ASD displaying symptoms associated with (C)AP difficulties (i.e., difficulty hearing in noise) may benefit from individualized interventions that target (C)AP skills. Research directed at whether or not specific interventions targeting (C)AP may benefit some individuals with ASD would be beneficial for the field. As suggested by ASHA [3], direct intervention, compensatory strategies, and environmental modifications may address specific (C)AP challenges. To date, evidence-based practices that target specific (C)AP skills in individuals with ASD is very limited. There are preliminary case studies and anecdotal reports that suggest use of personal amplification devices and direct dichotic listening therapy may be beneficial in increasing listening skills in some individuals with ASD, but more research is needed before methods are suggested for clinical use [30-32]. Finally, some early interventionists suggest that individuals with ASD can be identified as visual or auditory learners, and that auditory learners tend to experience a greater degree of success in traditional behavioral intensive early intervention programs [33]. The relationship between these interventionists' definition of auditory learners and (C)AP skill abilities could be explored in future research, which may eventually lead to better identification of learning style and determination of the of the most appropriate treatment options for the individual. Ultimately, research in these areas will lead to a better understanding of ASD and to improvements in individualized treatment programs that will help all individuals with ASD reach their full potential.

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