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CATEGORICAL PERCEPTION OF STOP CONSONANTS IN CHILDREN WITH AUTISM

by

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ABSTRACT

The purpose of this study is to determine whether children with autism recognize the same perceptual voicing boundaries of stop consonants as normally developing children of the same age group. This was explored using three groups of participants: ten children with autism between the ages of 8-14, five typically developing children between the ages of 8-14, and five typically developing seven-year-old children. Children in all groups listened to initial stop consonant syllables with voicing contrasts, with voiced [d] and voiceless [t] cognates presented. The initial consonants were altered along a voice onset time continuum within the typically perceived boundaries of each consonant. Participants were instructed to select the box containing the letter of the initial consonant they perceive when they hear each syllable. Results revealed greater difference between the responses of the children with autism when compared with the older control group, than when compared with the younger children. The responses of the children with autism were more similar to those of the children in the second control group. This could be indicative of a delay in the children with autism of perception of the categorical boundaries along the dimension of voice onset time compared to typical children's perception of these consonants.

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CHAPTER 1 - INTRODUCTION

Speech perception is a requisite skill to later speech and language development, and impairment may create downstream developmental deficits. Speech is a specially encoded signal which requires long term exposure to become proficient at analyzing, particularly at the rapid rate with which it is presented. Children acquire language through continuous exposure to the phonemes of their language and the patterns of speech. Fortunately the majority of children are bombarded by auditory input of speech stimuli from the moment they are born, and have no trouble learning to decode speech virtually independently based on this input. Hearing loss and auditory processing disorders interfere with this natural acquisition of language, because without constant ongoing exposure to the stream of speech it is difficult to form the necessary associations between sound and symbolic meaning.

Autism is characterized by language impairment, with severity determined at least in part by the level of this impairment (Schopler, Reichler, & Renner, 1994). As language acquisition depends on learning to decode the incoming auditory speech signal, the root cause of this language impairment could very well be the difficulty with which the autistic child extracts linguistic information received through auditory perception (Siegal & Blades, 2003).

Joint attention, another pivotal skill deficient in children with autism, is also reliant on audition, as it is difficult to share attention with others when messages and signals are unnoticed or misunderstood. Theories abound as to the neural bases of auditory perception in children with autism and the implications for language development, but most agree that there is a connection between impaired auditory perception and disordered language development (Alcantara, Weisblatt, Moore, & Bolton., 2004; Boddaert, Belin, Chabane, Poline, Barthelemy, Mouren-Simeoni, Brunelle, Samson, & Zilbovicius, 2003; Ceponiene, Lepisto, Shestakova, Vanhala, Alku, Naatanen, & Yaguchi, 2003; Foxton, Stewart, Barnard, Rodgers, Young, O'Brien, & Griffiths, 2003; Gervais, Belin, Boddaert, Leboyer, Coez, Sfaello, Barthelemy, Brunelle, Samson, & Zilbovicius, 2004; Heaton, 2003 & 2005; Kern, Trivedi, Garver, Grannemann, Andrews, Savla, Johnson, Mehta, & Schroeder, 2006; Muller, Behen, Rothermel, Chugaul, Muzik, O, Mangner, & Chugani, 1999; O'Riordan & Passetti, 2006; Samson, Mottron, Jemel, Belin, & Ciocca, 2006; Siegal & Blades, 2003). Language must be perceived to be decoded.

Categorical perception is the ability to perceive individual sounds in a set as different from nonmembers, despite differences between members (Ryalls, 1996). We perceive sounds of speech through categorical perception, assigning meaning to otherwise meaningless sounds and categorizing them with corresponding graphemes into our language. Consonants, particularly stops, are perceived categorically within parameters of voicing and place of articulation. Voicing is traditionally measured as voice onset time (VOT), the time between the burst or release and onset of phonation. Voiceless stops, such as /p/ or /t/, have VOTs between 50 and 80 milliseconds while voiced stops, such as /b/ or /d/, have VOTs between 0 and 25 milliseconds, or may be prevoiced with a negative voice onset time (Ryalls, 1996). Listeners tend to not perceive variations within those parameters, only those that cross the line between categories.

Sensory processing appears to be impaired across all modalities in individuals with autism, with deficits appearing in auditory, visual, tactile, and oral modalities. Various studies found patterns of sensory processing abnormalities among autistic populations, and correlations between deficits in different modalities (Kern *et al*., 2006 & 2007). Abnormally high and low thresholds of processing for these different modalities were found to interrelate, i.e. individuals with low scores in one modality had lower scores in all modalities. Low threshold is defined as defensiveness, and may be manifested as: tactile defensiveness as avoidance of touch, oral defensiveness as avoidance of certain foods, visual defensiveness as discomfort from bright lights, and auditory defensiveness as discomfort from certain noises or hyperacusis. High threshold is defined as insensitivity to stimuli or "sensory seeking". Many individuals with autism display low thresholds or defensiveness towards some stimuli with an insensitivity to other stimuli within the same modality. Obviously other factors besides intensity of stimuli must play a role in this selectivity of processing.

Mottron and Burack (2001) proposed the Enhanced Perceptual Functioning model as a framework for understanding the characteristics of autistic perception. This was an attempt to account for patterns of superior performance on certain domain specific, low level visual and auditory tasks, such as pattern recognition and pitch discrimination. This heightened and enhanced pattern recognition seems to be the apparent root of savant abilities observed in many, but not all, individuals with autism; such as musical performance due to superior pitch perception or mathematical ability due to superior recognition of numerical patterns. Mottron later proposed eight principles of autistic perception (Mottron, Dawson, Soulieres, Hubert, &

Burack, 2006): 1.) More locally oriented perception, 2.) Dissociation between neurally defined "simple" and "complex" tasks, 3.) Regulatory perceptual function of early atypical behaviors, 4.) Atypical activation of perceptual primary and associative brain regions, 5.) Optional higher-order processing, 6. Perceptual expertise basis of savant syndrome, 7.) Savant syndrome sub-typing model, and 8.) Enhanced primary perceptual brain region functioning accounts for autistic perceptual atypicalities. Their model suggests a skewing of the hierarchical axis towards posterior brain regions, resulting in enhanced low-level processing, such as recognition and discrimination with impaired higher level processing.

Another proposed model of perception and cognition involved in autism is the Weak Central Coherence theory (Frith & Happé, 1994), which suggests that individuals with autism tend to focus on perceptual details without integrating them into a cohesive whole or gestalt. This model was based on testing primarily in the visual domain, although abnormalities were predicted across all modalities. A study conducted to test this theory in the auditory domain using a same-different test of transposed musical sequences found participants with autism scored higher than normal controls (Foxton *et al*., 2003). The authors attributed this to the absence of auditory global interference in autism. The global effect of the transposition of melody had no detrimental effect on their processing of the local contour of pitch, unlike the control group, who performed better with untransposed material. Children with autism have also been found to display statistically significantly better detection of minute changes in pitch contour than age matched normal controls (Heaton, 2005), demonstrating detection of interval changes between 1-4 semitones, which was not observed in the control group. Children with autism also displayed better ability to detect convergence of paired tones than normal controls, which were unable to determine when the tones had become identical (O'Riordan & Passetti, 2006). These findings are evidence of the enhanced first order processing observed in individuals with autism.

A study using the McGurk effect to assess visual-auditory integration in autism found little differences between groups of participants with and without autism (Williams, Massaro, Peel, Bosseler, & Suddendorf, 2004), although this could be due to sampling errors, as one of the experimental groups was significantly smaller than the other two groups of participants. However, these researchers found the children with autism scored lower on recognition of unimodally presented auditory or visual speech stimuli. One could infer from these results that enhanced first order/impaired second order perception may be more involved than weak central coherence in the atypicality of speech perception among children with autism, suggesting that the Enhanced Perceptual Functioning model may be more appropriate than the Weak Central Coherence theory.

A meta-analysis on autistic patterns of performance on auditory tasks revealed a dissociation in autistic individuals between first and second order discrimination of auditory stimuli similar to previous findings involving visual stimuli (Samson *et al.*, 2006). When results of previously conducted studies were analyzed they demonstrated a pattern of enhanced first order and impaired second order auditory discrimination. The organization of the neural network involved in auditory perception is similar to that of the visual cortex, as they both involve the primary cortex for perception and the associative cortex for further processing. Therefore the authors had proposed a link between visual perception and auditory perception and predicted this similar dissociation for auditory perception.

Individuals with autism display a variety of atypical responses to auditory input, including: hyper-reactivity to low intensity sounds and spectrally complex sounds, hypo-reactivity to loud sounds and speech, high incidence of special musical talents, such as: perfect pitch, exceptional musical memory and exceptional improvisational skill. Complexity of auditory stimuli is separated into first and second orders. First order stimuli include simple stimuli, such as pure tones, and single frequencies. Second order stimuli are complex along two possible dimensions: spectral complexity, as in sounds containing several frequencies, such as chords or harmonic series and temporal complexity, or rapid changes, such as musical sequences or melodies. Speech sounds are both spectrally complex, including formants and harmonics, as well as being temporally complex, using rapid sequences of sounds for speech (Samson *et al*., 2006).

Samson, et al. (2006), employed results of previous studies to support their hypothesis, that the level of neural complexity explains performance level on auditory tasks for autistic individuals. Studies establishing enhanced first order discrimination found that perfect pitch was 500 times more frequent among individuals with autism (Rimland & Fein, 1988), children with autism had superior recall of pure tones (Heaton, Hermelin, & Pring, 1998), and adults with autism displayed superior discrimination of pure tones.

Results were higher for identification than discrimination, which supports their hypothesis as identification uses a simpler neural network, as identification compares stimuli with mental model rather than a newly presented tone. Autistic adults & children displayed enhanced chord disembedding, which is a first order task, determining whether a tone is part of a chord (Miller, 1989; Mottron, Peretz, Belleville, & Rouleau, 1999; Heaton, 2003). Individuals with autism also demonstrated superior discrimination of direction of minute interval changes, but not superior detection of global contour of pitch in melody. This implies a focus on simpler features of pitch, ignoring complexity of contour and timing (Heaton, Pring, & Hermelin, 1999). Studies have established impaired second order discrimination included findings such as: hypersensitivity to sound changes & amplified perception of sound in autistic population (Bruneau & Gomot, 2005), and deficits in automatic attention among children with autism to complex tones and vowels, but not pure tones (Ceponiene *et al*., 2003). Adults with autism demonstrated inferior speech recognition scores compared to normal controls in the presence of noise with temporal-spectral dips (Alcantara *et al*., 2004).

Temporal information processing is an essential component in many cognitive functions deficient in autism; perception, attention, memory, and communication. (Szelag, Kowalska, Galkowski, & Poppel, 2004). In a study on temporal processing of children with autism, participants were binaurally presented with 200 Hz pure tones of randomly varying durations. Participants had to reproduce the duration of the tone by pushing a key to switch the tone off after the same duration.

The children with autism in the study were unable to reproduce the intervals demonstrating temporal neglect, a deficiency of time judgment, which is affected by factors such as memory and attention. Errors may be due to inaccurate memory of duration, or to impatience, which could result not only in shorter durations seeming longer, but less attention paid to longer durations. All are factors affected by temporal integration.

According to another study (Pöppel, 1997), temporal integration is the basis for a temporal platform, a mental construct which links events successively in 2-3 second intervals. Results of the previous study could indicate residual use of temporal integration as the autistic participants favored three second response intervals throughout the study, regardless of stimuli duration.

Studies conducted with children with language-based learning impairments achieved positive results using computer based adaptive training exercises designed to target temporal processing skills. (Merzenich, Jenkins, Johnston, Schreiner, Miller, & Tallal, 1996). The program used was “Fast ForWord”, a series of computer games, each with five levels. At the simplest level frequencies, speech durations are slowed, transitions lengthened and amplitudes filtered acoustically to emphasize target sounds in the exercise. The sounds are filtered progressively less at each level, until at the fifth level they are not filtered at all, but representative of normal adult speech. Temporal processing skills, such as distinguishing between rapidly changing tones, are drilled repeatedly in auditory-visual game format. Merzenich and colleagues found marked improvements in recognition of rapid and brief speech stimuli sequences among children with language learning impairments after 8 to 16 hours of training over a 20 day period. Similar improvements may be seen with children with autism if temporal processing deficits are the root of their auditory atypicalities (Tallal, Saunders, Miller, S., Jenkins, Protopapas, & Merzenich, 1997).

Neuro-imaging studies have found various atypicalities in the auditory functioning of individuals with autism. Two studies found decreased activity in the associative auditory cortices and temporal regions in the brains of children with autism (Ohnishi, Matsuda, Hashimoto, Kunihiro, Nishikawa, Uema, & Sasaki, 2000; Zilbovicius, Boddaert, Belin, Poline, Remy, Mangin, Thivard, Barthelemy, & Samson, 2000). fMRI studies of high functioning autistic participants have found lack of activation when hearing verbal stimuli in regions of the superior temporal sulcus normally activated when listening to speech (Gervais *et al*., 2004), and evidence of underconnectivity in cortical activation during sentence comprehension (Just, Cherkasky, Keller, & Minshew, 2004), suggesting lower synchronization and integration of information across speech processing cortical networks in autism (Just *et al*., 2004). Many children with autism displayed asymmetrical activation in the olivocochlear system during speech in noise detection tasks (Siegal & Blades, 2003). A study of cortical event-related brain potentials of children with autism found attentional differences in auditory speech perception, again implying some selective filtering of auditory input (Ceponiene *et al*., 2003).

Autistic individuals often present with hemispheric atypicalities during speech processing. A study of adults with autism revealed atypical right hemisphere dominance in the auditory temporal cortex and reduced activity in the temporal gyrus in an area associated with word retrieval while listening to synthesized speech (Boddaert *et al*., 2003). A PET study of auditory perception in high-functioning autistic adults found reversed hemispheric dominance while listening to verbal auditory stimuli (Muller *et al*., 1999). Although participants were nearly all right handed (one mixed handed), a significant reversal of normal left hemispheric dominance was seen while participants were listening to sentences.

Critical stages of language development are linked with left hemisphere maturation (Chiro, Leboyer, Leon, Jambaqué, Nuttin, & Syrota, 1995). Is there a relation between right hemispheric dominance and language perception? A study measuring averaged cortical evoked responses of children with autism revealed patterns of reversed hemispheric dominance (Dawson, Finley, Phillips, & Galpert, 1986). This would seem to correlate with language development, the children with autism with more advanced language development displayed less right hemisphere dominance. It appears that the left hemisphere fails to develop normally due to lack of auditory language stimulation, while the right hemisphere is stimulated by the autistic child's interest in visuo-spatial tasks. Potentially, language acquisition may eventually cause the switch from right hemispheric to left hemispheric dominance in children with autism.

Categorical perception is defined as insensitivity to differences within a category, with keen sensitivity to differences between categories (Ryalls, 1996). It is what allows us to easily identify the rapidly changing phonemes we hear in speech. Infants have been found to demonstrate an innate ability to categorize speech sounds along the dimension of Voice Onset Time (Eimas, Siqueland, Jusczyk, & Vigorito, 1971). They later begin to develop categorical discrimination for phonemes of their native language in the first year of life, perceiving minute changes between categories, but no longer perceiving larger variations within categories. Their perception shifts to a phonemic or language-specific perception rather than their previous universal-language phonetic perception. Children refine their ability to differentiate the phonemic contrasts of their own language while simultaneously losing the ability to distinguish acoustic parameters of non-native languages (Strange, 1986). It would seem that categorical perception is at the foundation of auditory language perception, which is, in turn, the basis for learning to decode the incoming signal in order to acquire receptive language and finally expressively produce language. Obviously deficiencies in categorical perception could have an enormous impact on a developing child's acquisition of oral language.

A study on categorical perception in high functioning individuals with autism using unidimensional visual stimuli found no facilitation of discrimination near the boundaries between categories generally perceived by typically developing individuals (Soulieres, Mottron, Saumier, & Larochelle, 2007). This study used a series of ellipses, varying in width along a continuum of 1.4 to 4.1 cm., with subjects instructed to determine whether pairs were the same or different. These results demonstrate atypical categorical perception, at least in the visual domain, among individuals with autism. Results are also indicative of reduced involvement of top-down processing in perception, as discriminatory autonomy was increased relative to categorization, with no connection between the higher level perception of category to the lower level visual discrimination.

Sussman conducted a study looking at perception of formant transitions for place of articulation among language-impaired children (Sussman, 1993). Participants were presented with auditory verbal stimuli consisting of five-formant syllables transitioning along a seven step continuum from bilabial [ba] to alveolar [da], primarily by altering second and third formant transitions. Testing involved discrimination (same-different) and identification (categorization) procedures. Although the language impaired children scored somewhat lower than controls on the discrimination tasks, they were far more impaired on the identification tasks then on the discrimination tasks compared to normal controls. These results revealed the language impaired children to have much more difficulty with the categorization aspect. Normally developing children tended to have difficulty with discrimination until about age 10 or 11, although they achieved adult-like categorization of speech sounds by six years of age. This implies that language impaired children may display near normal auditory discrimination but have severe impairments in categorical perception of phonemes.

CHAPTER 2 - MATERIALS AND METHODS

Participants in this study were 10 children with autism between the ages of 7 and 14, in the experimental group (Group A), and 10 typically developing children between the ages of 7 and 14, who served as a control group. Children in the control group were divided by age into two separate subgroups, to investigate the effects of age and maturation, with children older than seven in the first group (Group B) and seven year olds in the second group (Group C). All participants were screened for hearing loss using pure tone audiometry, using a Grason-Stadler GSI-17 audiometer with the threshold set at 20 dB. All participants with autism must have had an independent diagnosis of autism (DSM-IV, American Psychiatric Association, 1994). Severity of autism was determined using the CARS scale (Schopler *et al*., 1994), a 15 item behavioral scale, commonly used as a quantitative measure of severity level of autism. Participants in the experimental group ranged from mild to severe in their severity level, with the range of levels (mild, mild to moderate, and severe) represented in this study. Participants for experimental group were recruited through email solicitations to parents of children with autism currently involved with the UCF Center for Autism and Related Disabilities. Normally developing children for the control group were recruited using flyers given to parents with children participating in local community after-school programs. The recruitment process was approved by the UCF Internal Review Board.

Table 1 - Group A Participants

Participant	Age	Gender	Autism Severity
1	9	female	mild
2	9	male	mild-moderate
3	8	male	moderate
4	12	female	mild
5	10	female	moderate-severe
6	10	male	mild-moderate
7	12	male	severe
8	8	male	mild
9	14	female	severe
10	11	male	severe

Table 2 - Group B Participants

Participant	Age	Gender
1	8	female
2	10	male
3	12	male
4	13	female
5	14	male

Table 3 - Group C Participants

Participant	Age	Gender
1	7	male
2	7	female
3	7	female
4	7	female
5	7	female

Identification of stop consonants with regard to category was explored; participants were binaurally presented with synthesized speech consisting of stop-consonant initial CV syllables. Voice onset time was altered along the continuum between voiced and voiceless stop consonant cognates with participants indicating their choice of voicing category by selecting the initial consonant perceived.

Stimulus items were provided by Dr. Sheila Blumstein from Brown University, with editing and measures of voice onset time performed using BLISS software. BLISS is a computer speech analysis program which allows for sound measurement and editing. Voice onset times of stimuli were altered along a continuum between -15 ms to 40 ms, divided into five separate intervals.

Participants were seated in a quiet room, with stimuli being presented via compact disc through stereo speakers. Testing was conducted at two separate locations, to accommodate the parents and children, with regards to time availability and distance traveled. Both locations provide a private, quiet room in which to conduct testing. Stimuli were syllables: [da], and [ta], with voice onset times varying along the aforementioned continuum. Five different voice onset time stimuli items were used: #1 = -15 ms, #2 = 15ms, #3 = 20ms, #4 = 30ms and #5 = 40ms. Stimuli were presented in randomized order, ten times each to each participant. Participants were trained to point to the letter on a card to indicate their choice of perceived initial phoneme. Participants were presented with individual syllables [da] or [ta], and instructed to point to the box containing the first letter of the sound they thought they heard. Stimuli with voice onset time over 30 ms are generally considered to be voiceless, while stimuli with voice onset times below 30 ms are generally considered voiced (Ryalls, 1996). Participants' responses were recorded manually by examiners, who circled letters on a response sheet corresponding to the participants' choice. Responses were scored by comparison with a master key, with corresponding item numbers for each of the five stimuli presented.

CHAPTER 3 - RESULTS

Participants responses were converted to percentages for each stimulus item, with means determined for each item presented and represented as a percentage. In this format, 100% represented “d” responses for every presentation of that item, and 0% (meaning 0% “d” responses) indicated “t” responses for every presentation of an item. Group means for each item were also calculated. Results were then plotted on line graphs and visually compared for degree of slope between items.

Many of the ten children with autism in the experimental group (Group A) produced similar response patterns. Five of these children, fully half of the group, responded with 100% “d” to every stimulus item presented. Several of them made comments such as “Is he going to say something else?”, “It keeps saying the same thing”, and “When is it going to change?”. These children appeared to be quite attentive to the stimuli, but perceived no change between items. One child responded with “t” to every item presented (represented as 0% “d” in the graphs), also commenting on the lack of variation, saying “This is stupid, he just keeps saying ‘ta’.”. One child’s responses varied between 50-60% “d” for each item, while another child’s responses varied between 70-80% “d” for items 1-4, with item #5 falling to 50% “d”. Another child, although appearing focused on the task, produced responses seemingly unrelated to the stimuli, with item #1 at 10% “d”, item #2 at 40% “d”, item #3 at 50% “d”, item #4 at 40% “d”, and item #5 at 0% “d”, virtually forming a parabola when plotted on a line graph, far from the expected downward sloping line. Only one child in Group A produced this downward sloping line when charted, although results fell between 90-30% “d”, with no clear 100% or 0% response means. As expected, when group means were plotted (see table 1), they formed a nearly flat line, with means for each item as follows: item #1 (*M*=74%, *SD*=36.7), item #2 (*M*=74%, *SD*=32.6), item #3 (*M*=76%, *SD*=31.7), item #4 (*M*=71%, *SD*=33.6), and item #5 (*M*=63%. *SD*=40.3). Group A’s individual responses for each item ranged from 0% to 100% for every item, as one child responses were consistently “t” and five children responded “d” for every stimulus item.

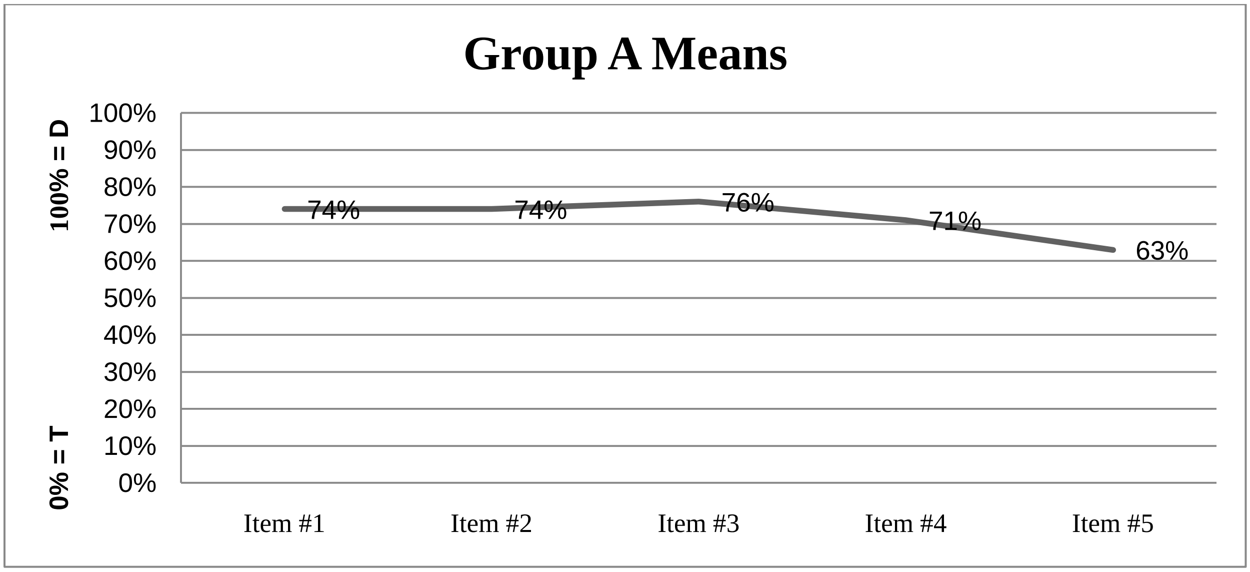


Figure 1 - Group A Results

Group B, consisting of five typically developing children in the older age group, ranging from 8 – 14 years of age, produced very different results from Group A. All of the children in this group had individual response means of 100% “d” for item #1 and 0% “d” for item #5, as expected. Three children in this group also responded 100% “d” for item #2, the other two children averaged 90% “d” for this item. Item #3 elicited more variation of response from this group, with responses of 20%, 60%, 70%, 80%, and 100% “d”.   Responses to item #4 also varied, from 0%, 10%, 20%, 40% to 100% “d”. When plotted on a line graph (see Table 2), this group’s results produced a steeply downward sloping line, with means as follows: item #1 (*M*=100%, *SD*=0), item #2 (*M*= 96%, *SD*=4.9), item #3 (*M*=66%, *SD*=26.5), item #4 (*M*=34%, *SD*=35.6), and item #5 (*M*=0%, *SD*=0). The range of individual responses from Group B were far less dispersed than those of Group A. All Group B participants responded 100% “d” for item #1. Reponses for item # 2 ranged between 90-100%, and between 20-100% for item #3. Responses to item #4 varied the most for this group, spanning the full range from 0-100%. All Group B members responded “t” to item #5, or 0% “d” for all responses.

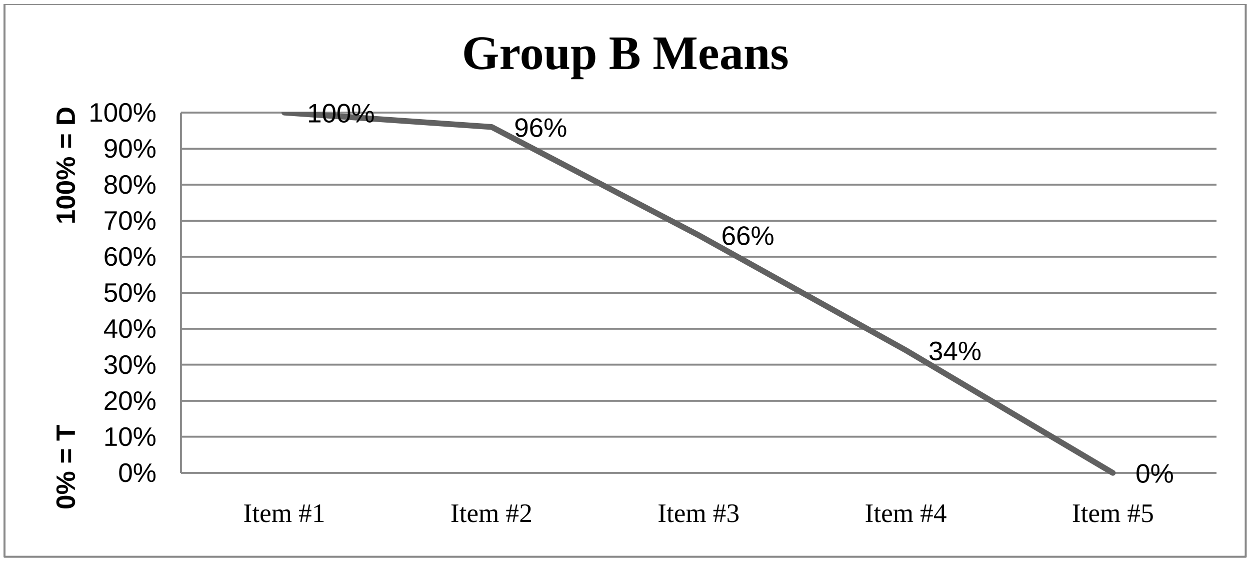


Figure 2 - Group B Results

The last group consisted of typically developing seven-year-old children. Two children in this group produced the same response pattern seen in the majority of the children in the experimental group, with 100% “d” means for each stimulus item presented. One of these children, like several of the children in the experimental group, also commented "When is he going to say something different?", also adding "It sounds like he's speaking Spanish." Another child in this group produced all 100% "d" responses to each item, except for item #3, for which they averaged 90% "d".

One child responses were 100% "d" for items #1, 2 and 4, and 90% "d" for items # 3 and 5. Only one child in this group produced responses similar to the typical children in the older group, with 100% "d" responses for items 1 and 2, 70% "d" for item #3, and 0% "d" for items 4 and 5. This child's responses, when plotted on a graph, produced the steeply downward sloping line similar to all of the children in Group B. The means of this group's responses, when plotted on a line graph (see Table 3), produce a pattern similar to Group A's response chart, with a gradual slope, with means as follows: item #1 (M=100%, SD=0), item #2(M=100%, SD=0), item #3 (M=90%, SD=11), item #4 (M=80%, SD=40), and item #5 (M=78%. SD=39.1), All Group C members responded 100% "d" to items # 1 and 2. Group C's individual responses for item #3 ranged from 70-100% "d", and responses for items #4 and 5 ranged from 0–100%, although only one child responded with other than 90-100% "d" for any items

Group A, made up of children with autism, aged 8-14, produced responses far more similar to the responses produced by the seven year old typically developing children in Group C than to those of the typically developing children of their own age group. The children in both Group A and Group C tended to be insensitive to the differences between the voiced and voiceless cognates, with members of both of these groups commenting on the lack of variation, with no members of Group B making comments of this type. It is interesting to note that one of the children in Group A who was rated as severe (Participant #7) on the CARS scale (Schopler *et* *al*., 1994) achieved the closest results to those of the age matched peers, represented by a steeply sloping line, while two of the children rated as mild (Participants #1 and #4) responded with 100% “d”, creating the same flat line graph results produced by the majority of participants in Group A. It would appear that the autism severity level as reported by the parents did not correlate with the ability to identify speech sounds.

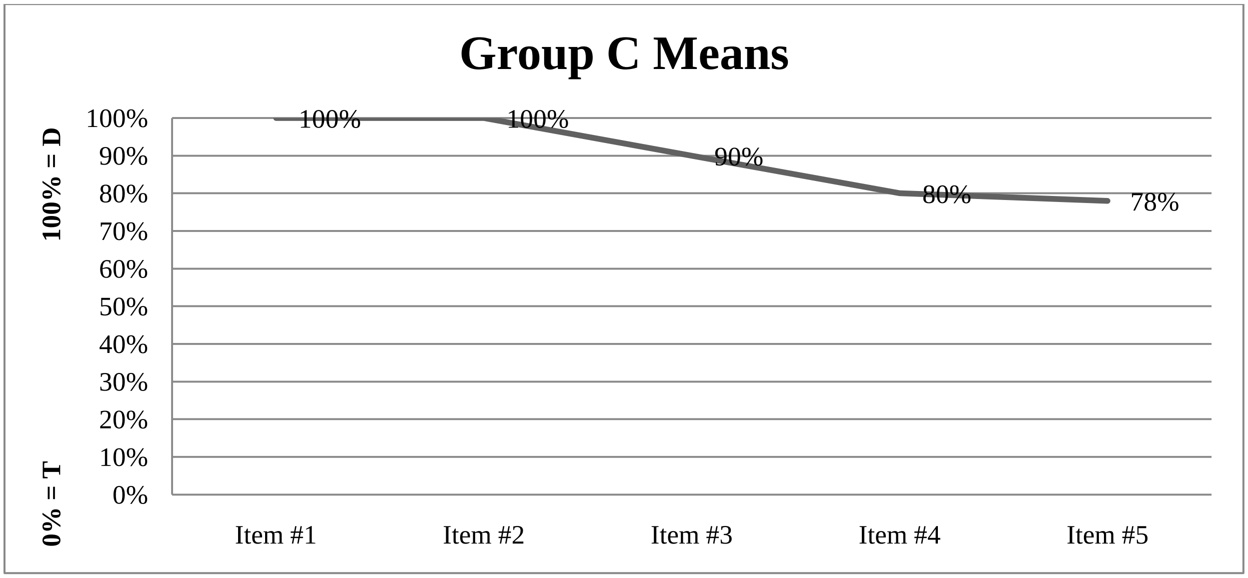


Figure 3 - Group C Results

So to summarize, the children with autism produced responses on this identification task more similar to those of the younger controls than the age-matched controls. The children with autism tended to be unable to accurately identify the presented speech sounds, even commenting that there was no difference between sounds. This was also observed in the younger controls, but not in the age-matched controls.

CHAPTER 4 - DISCUSSION

The purpose of this study was to examine the ability of children with autism to recognize speech sounds compared to their age-matched peers. Participants in this study listened to CV syllables and identified the initial consonant. This differs from discrimination tasks, which involve comparing stimuli to determine similarity or difference. Identification involves labeling the phoneme, in this case “d” or “t”. Voice Onset Time was manipulated along a continuum between the voiced and voiceless parameters. Results show that participants in the experimental group of children with autism (Group A) had more difficulty accurately identifying the phonemes they heard than members of the age-matched control group (Group B). However, the children with autism produced results more similar to the younger controls in Group C, which consisted of typically developing seven-year-olds. This could indicate a specific area of delay in the ability to categorically perceive consonants in children with autism, making them comparable to younger children rather than to children their own age. If the ability to identify the sounds of speech is so severely delayed in children with autism, it could be the root of the severe expressive and receptive language delays common to this population.

The range of responses varied greatly between groups. The children with autism produced responses ranging from 0% to 100% “d” for every stimulus item presented, as half of the group believed all sounds presented were “da”, and one child believed every sound was “ta”. the normally developing age-matched controls in Group B demonstrated far less variability than Group A, with less widely dispersed responses. All children in this group responded consistently for two stimulus items, with 100% “d” for item #1, and 0% “d” for item 5. Reponses for item # 2 ranged by a narrow 10% margin. The ranges for items #2 and 3 were broader, with an 80% range for item #3.and item #4 ranging from 0-100%. The younger children in control Group C also consistently responded to two items; items # 1 and 2 both received 100% “d” responses from all group members. Their responses for item #3 ranged by 30% “d”. Group C’s individual responses for items #4 and 5 ranged by 100%. Broader range of responses may be somewhat skewed for this group, as only one child’s responses varied greatly, all other children in this group responded within a 10% margin, with 90-100% “d” responses for all items by all other members. The children with autism in Group A produced the broadest range of responses among all group, with a high degree of variability among group member responses.

According to Strange (1986), typically developing children refine their ability to discriminate phonemic contrasts of their native language at a very early age, although identification or labeling these phonemes may still be a difficult task for them. The children with autism and most of the seven year old observed in this study were observed to have great difficulty with the identification task used in this study. Future studies exploring phonemic perception in children with autism could compare their abilities in phonemic identification and discrimination to determine whether a dichotomy exists between their skill levels in these areas. If so, perhaps identification is a later developing skill than discrimination in children with autism. If categorical perception is a precursor of auditory language perception, which in turn affects the acquisition of receptive and expressive language, these categorical perception deficits could play a role in the disordered language abilities of children with autism.

Results of this study are in concurrence with the study by Soulieres, et al (2007) on visual categorical perception in high functioning individuals with autism, which uncovered limitations in discrimination between categories of one-dimensional visual stimuli. Their results demonstrated diminished visual categorical perception in individuals with autism, similar to the results of this study in the auditory domain. In the Soulieres study, identification of category was tested, as well as discrimination, using a same-different task contrasting adjacent stimuli along a continuum. Although the Soulieres study was conducted in the visual domain, a similar process could be employed, with auditory stimuli such as the Voice Onset Time continuum used in our study, to contrast phonemic discrimination from identification skills. As in the Soulieres study, a dichotomy between these abilities may suggest more autonomous discrimination, without reference to categories, possibly indicating a reduced influence of top-down processing in lower level perceptual tasks.

In another study involving language-impaired children and abilities for discrimination and categorical perception of speech sounds (Sussman, 1993), language-impaired children demonstrated more difficulty on identification than discrimination tasks, indicating greater impairment in categorization of speech sounds. Sussman discovered typically developing children generally developed adult-like speech sound categorization by six years of age. While our study revealed that this categorization skill to be far greater in typically developing children of eight years of age and older, this is only a difference of about two years. The implication Sussman drew was that language impaired children may display near normal auditory discrimination but still have severe impairments in identification of phonemes. Such interpretations may also apply to children with autism.

While auditory and categorical perception may be disordered or delayed in children with autism, more research needs to be completed in this area to determine specific areas of deficit and possible targets for therapeutic implementation. Perhaps interventions which target temporal processing skills, such as the computer-based Fast ForWord Language program could facilitate development of these skills. Studies of Fast ForWord achieved positive results with children with language-based learning impairments (Merzenich, *et al*., 1996), which uses computer exercises to train both discrimination and identification abilities. Similar results might also be achieved by children with autism.

The possible dichotomy between discrimination and identification observed in the aforementioned studies is an area which should be further explored in this population. In a study examining perception of Voice Onset Time using discrimination and identification tasks (Blumstein, 1978), some individuals with aphasia who were unable to identify phonemes demonstrated an ability to make discriminations along the same parameters observed in normal controls. These results may be indicative of a prelinguistic discriminatory level of processing, which detects the boundaries of these sounds without the ability to classify the sounds in the typically recognized categories.

If discrimination is discovered to be superior to identification abilities in children with autism, perhaps therapeutic activities could be structured to develop categorization skills by building on the enhanced discriminatory abilities. If children with autism, and possibly children with other types of language impairments have the ability to discriminate between phonemes, interventions could refine this skill to facilitate the development of labeling abilities.

Another limitation which must be taken into consideration in this study is the sample size in the experimental group, as well as the controls. Larger samples may be more representative of the general population. Although a range of ages was examined, a larger sample could allow for a broader range of ages and more representatives of each age group considered. A larger sample could have also explored differences between severity levels of autism and identification abilities, as there would be more participants representative of each level of severity.

In conclusion, this study revealed decreased identification of phonemes among children with autism. This is consistent with previous studies of categorical perception in children with autism using tonal and visual stimuli. The results indicate greater similarity between the responses of the children with autism and those of the younger control group than with the age-matched controls, possibly indicating that this may be a delayed skill in this population. The implications of this may be that children with autism have greater difficulty identifying the categorical parameters which define these sounds than typically developing children of the same age. Phonemic identification is an essential component in the decoding of speech, and this ability appears to be disordered or delayed in children with autism. If this is true, therapeutic interventions focusing on development of identification skills in children with autism could significantly improve their receptive and expressive language abilities.

APPENDIX A - GROUP A INDIVIDUAL RESULTS

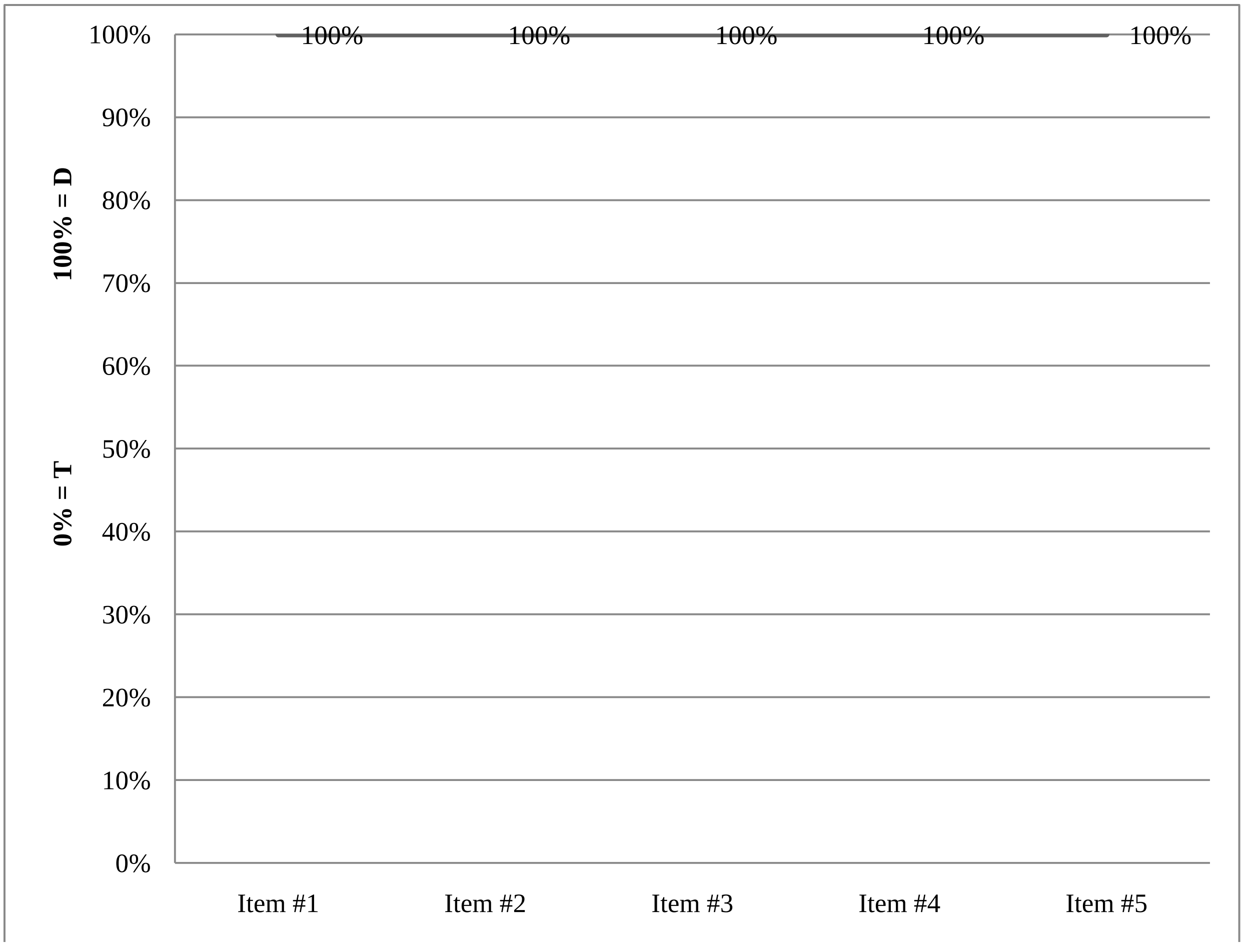


Figure 4 - Group A, Participant #1 Results

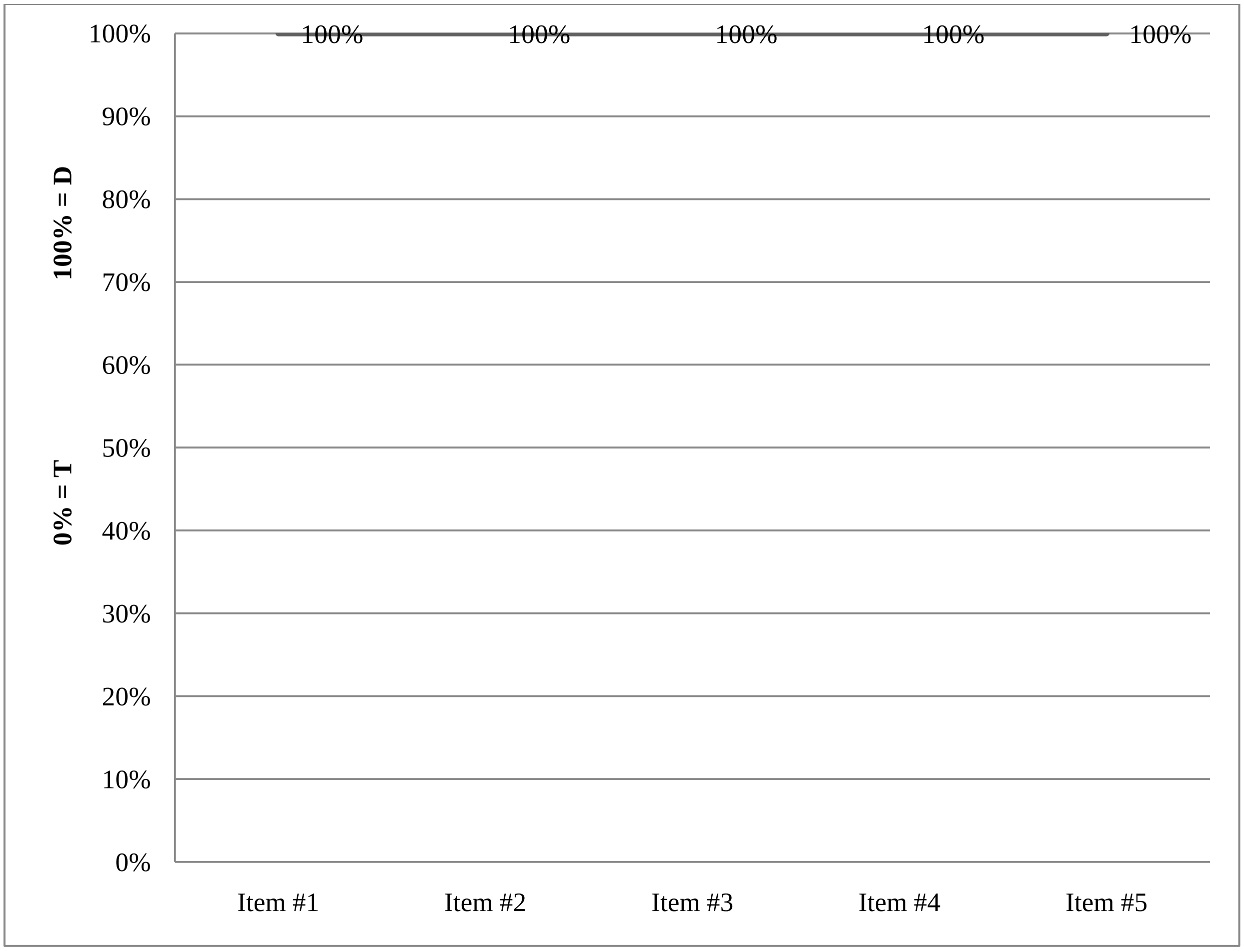


Figure 5 - Group A, Participant #2 Results

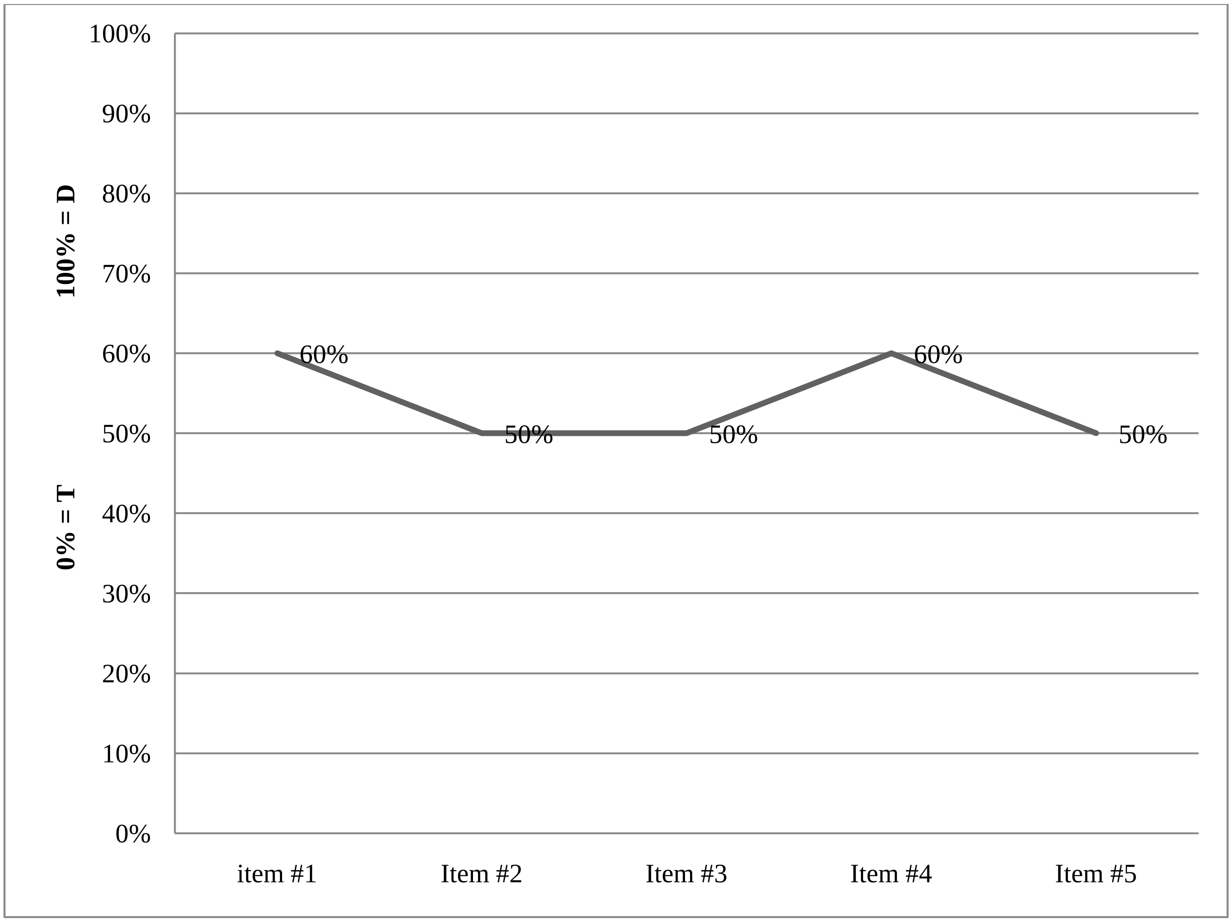


Figure 6 - Group A, Participant #3 Results

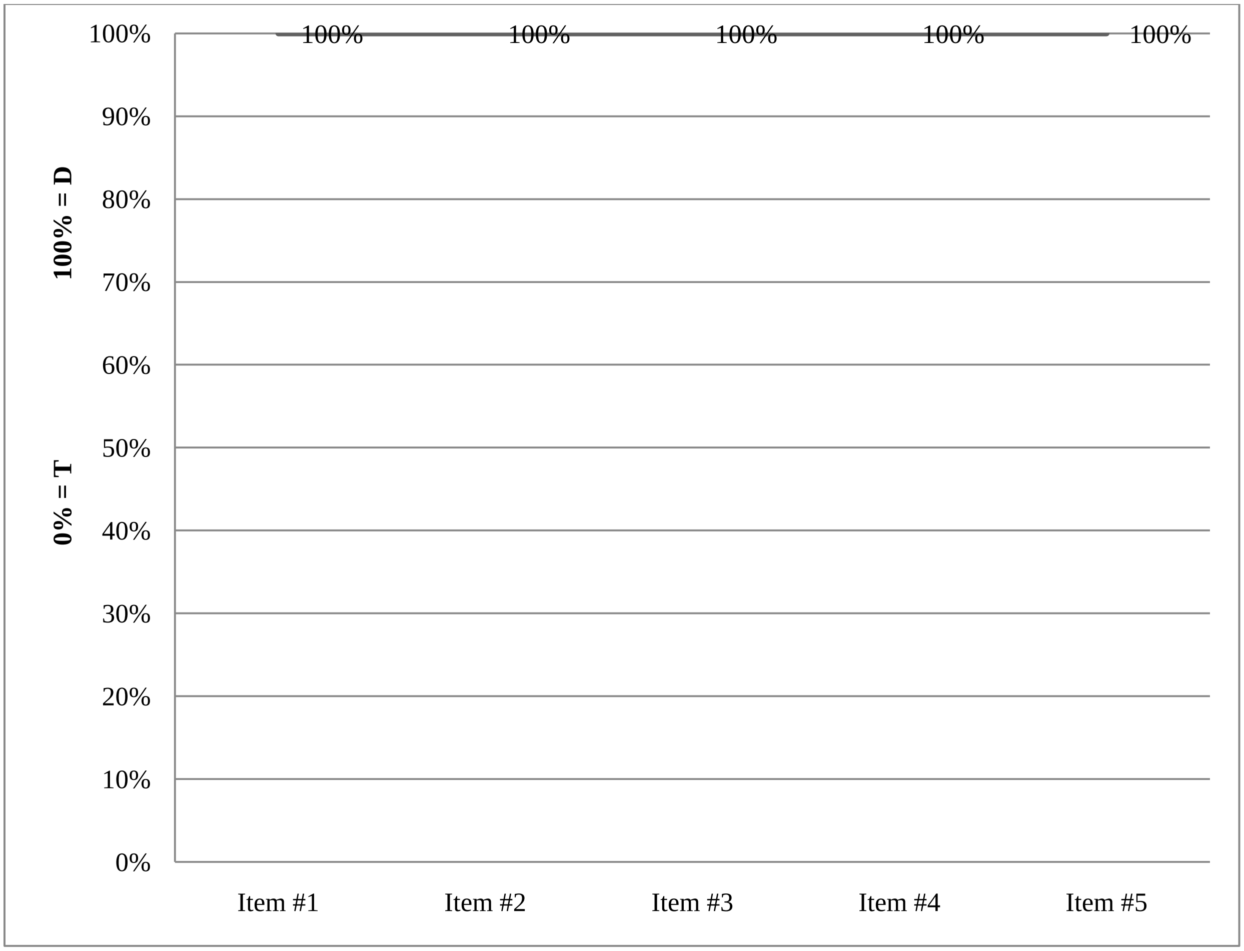


Figure 7 - Group A, Participant #4 Results

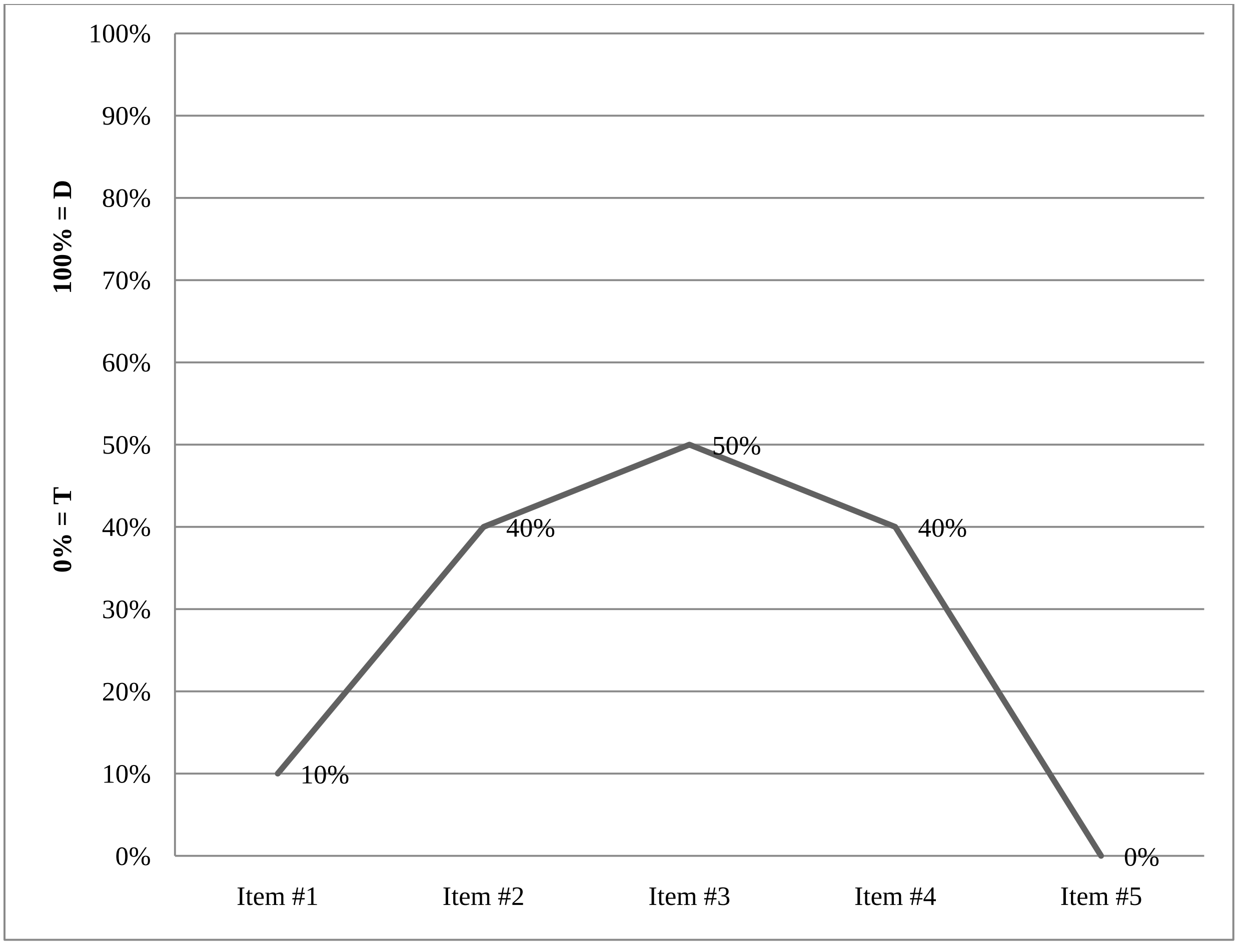


Figure 8 - Group A, Participant #5 Results

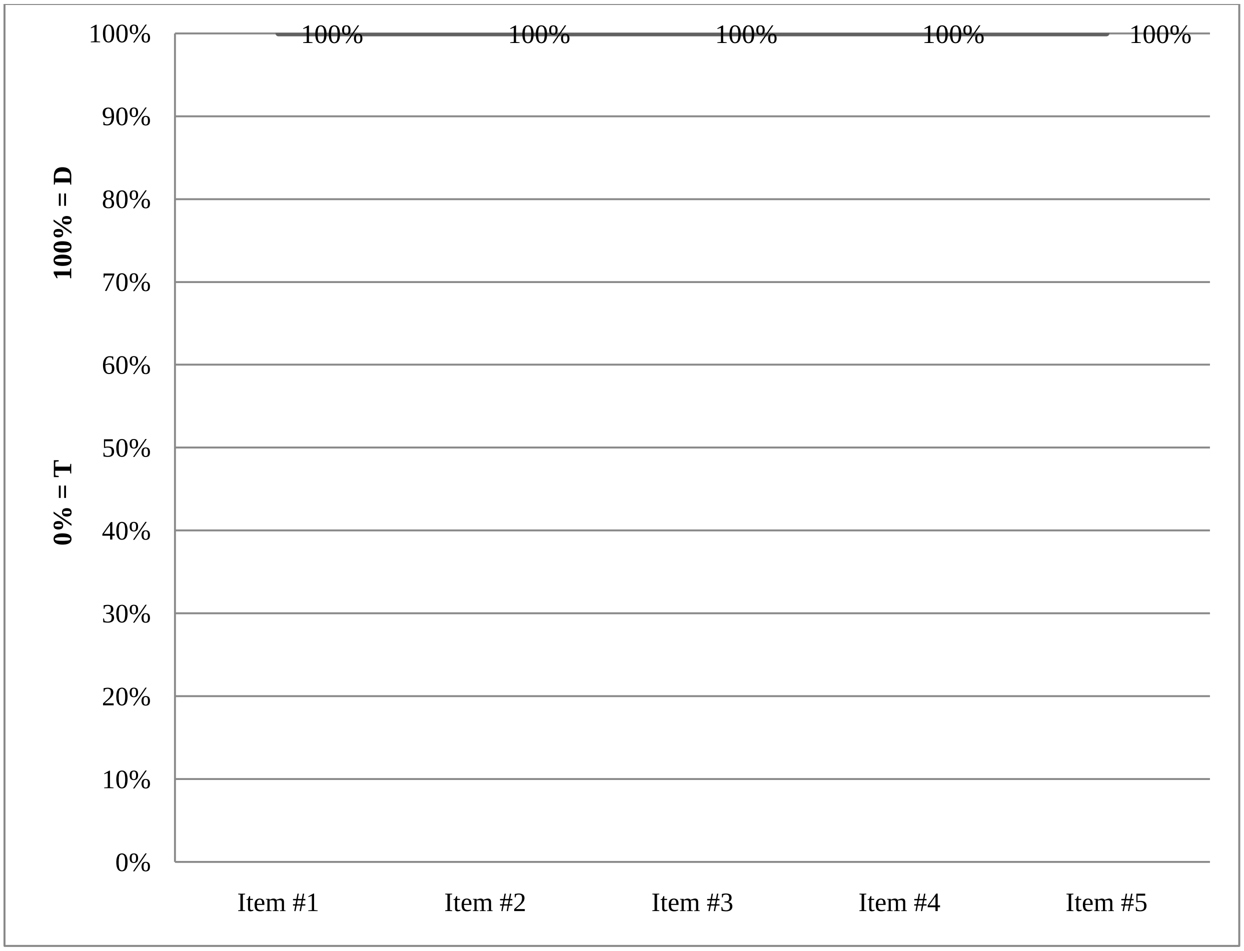


Figure 9 - Group A, Participant #6 Results

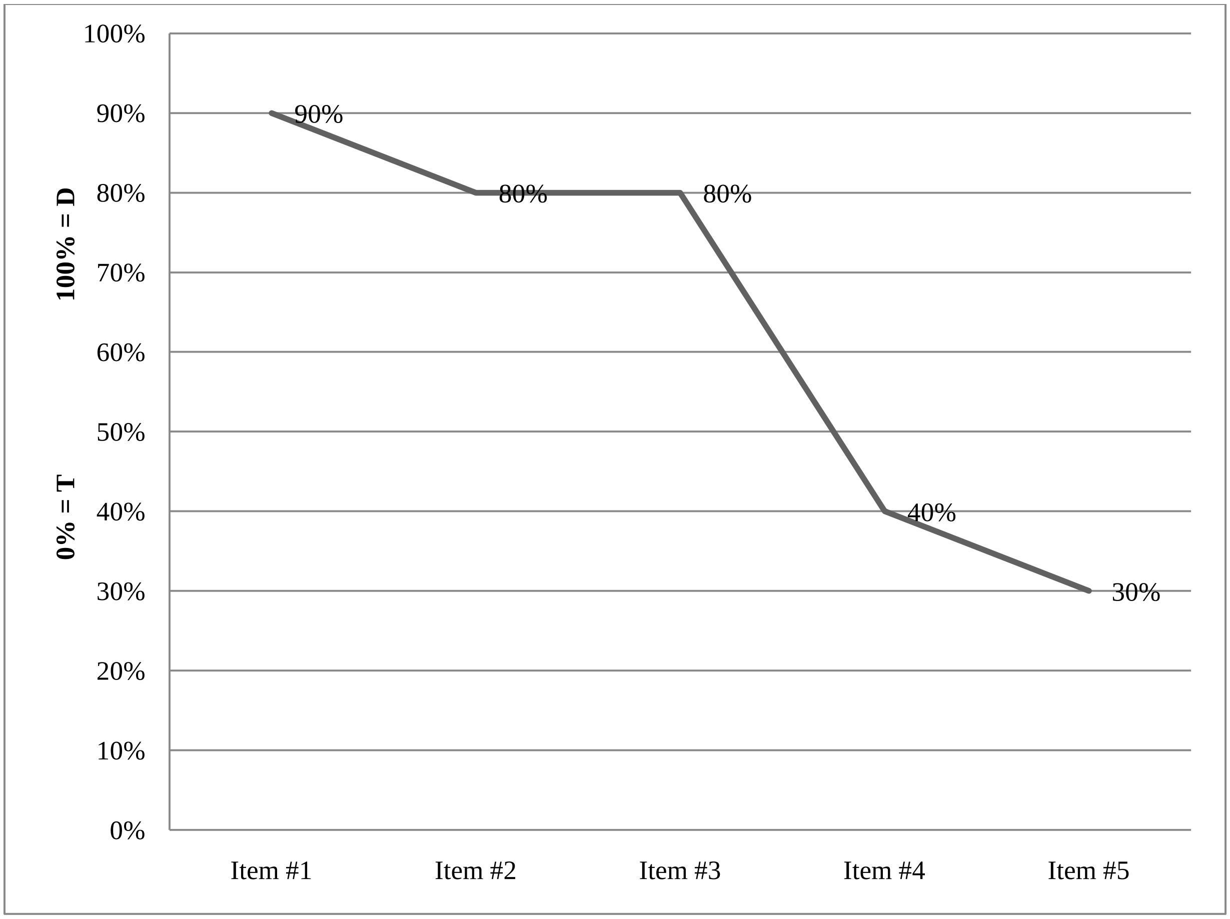


Figure 10 - Group A, Participant #7 Results

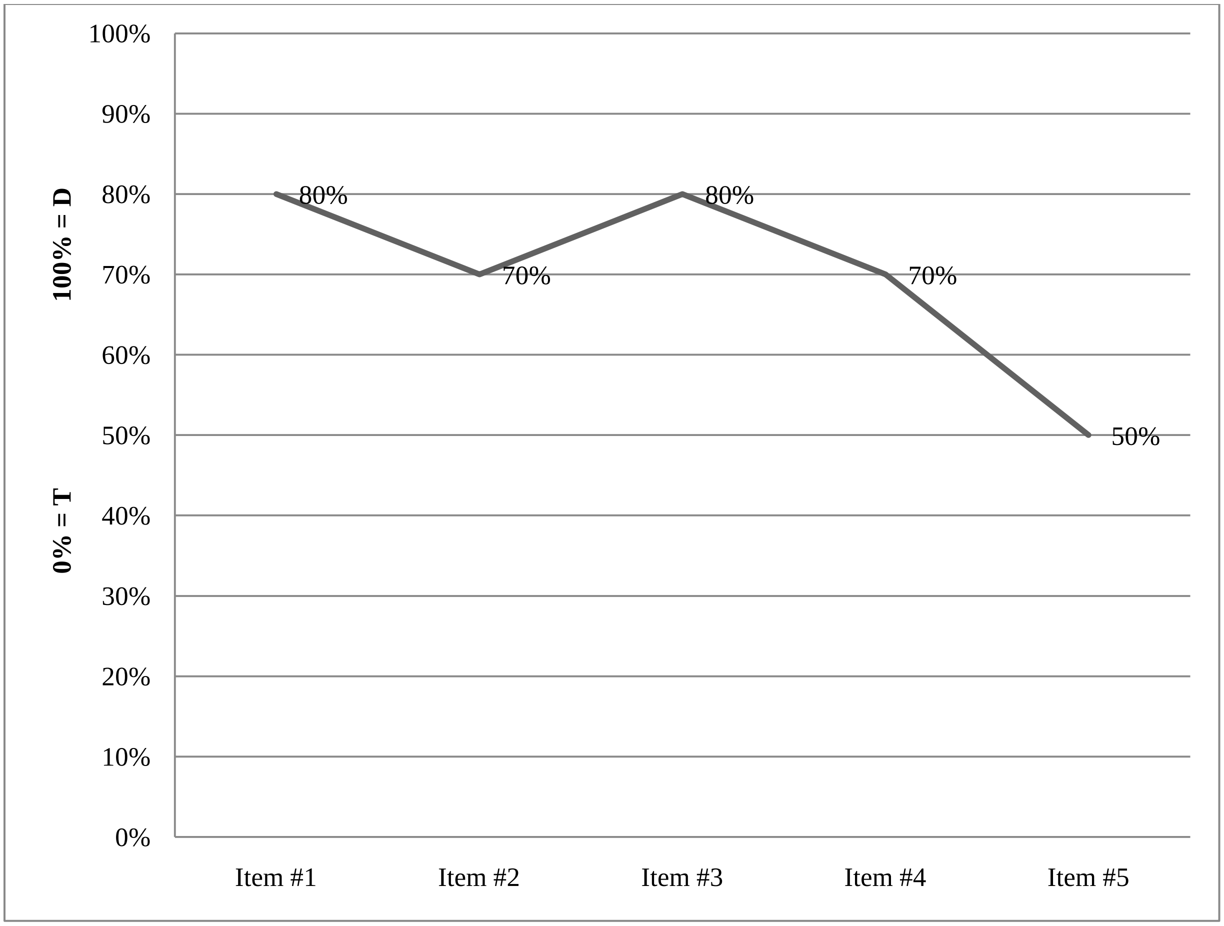


Figure 11 - Group A, Participant #8 Results

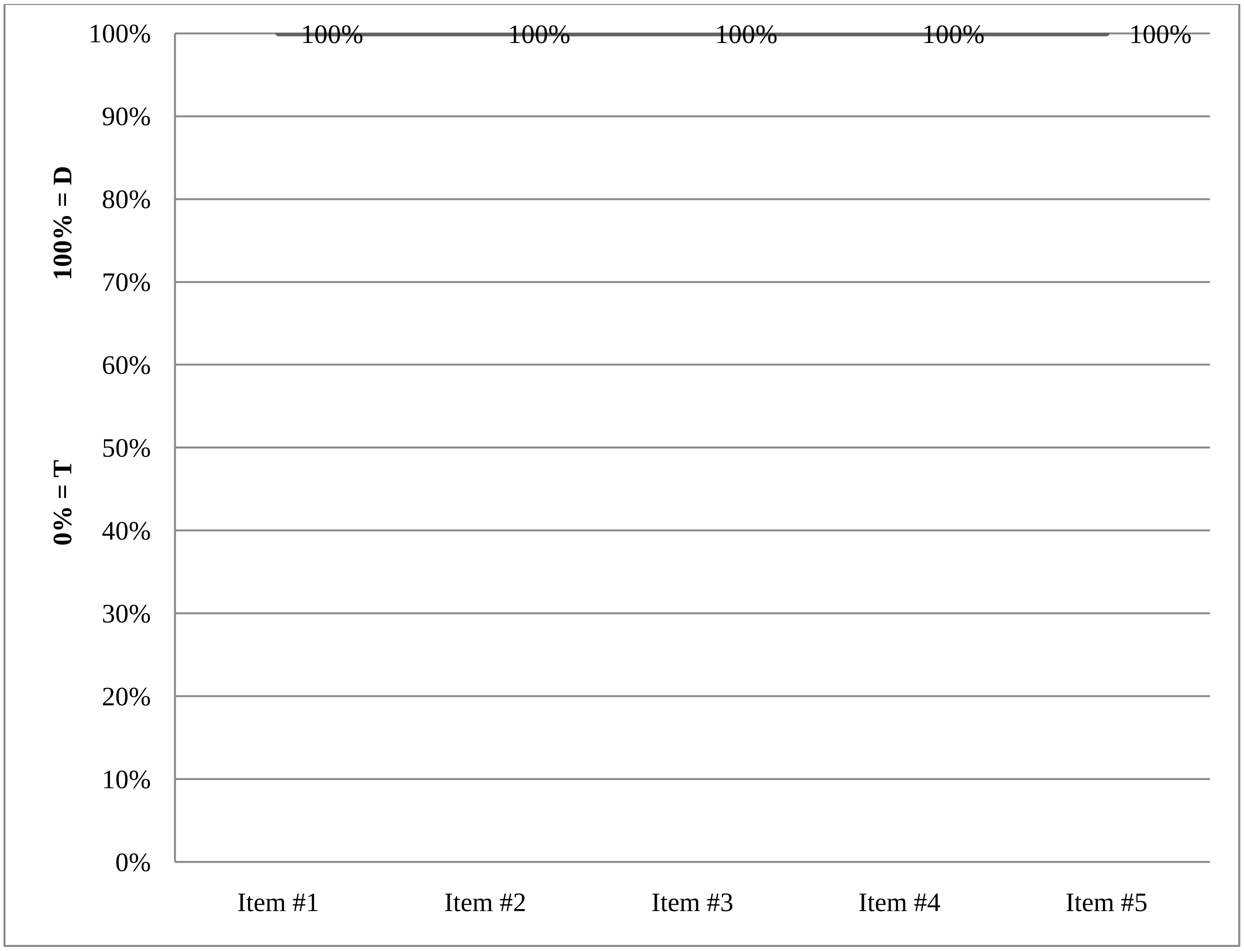


Figure 12 - Group A, Participant #9 Results

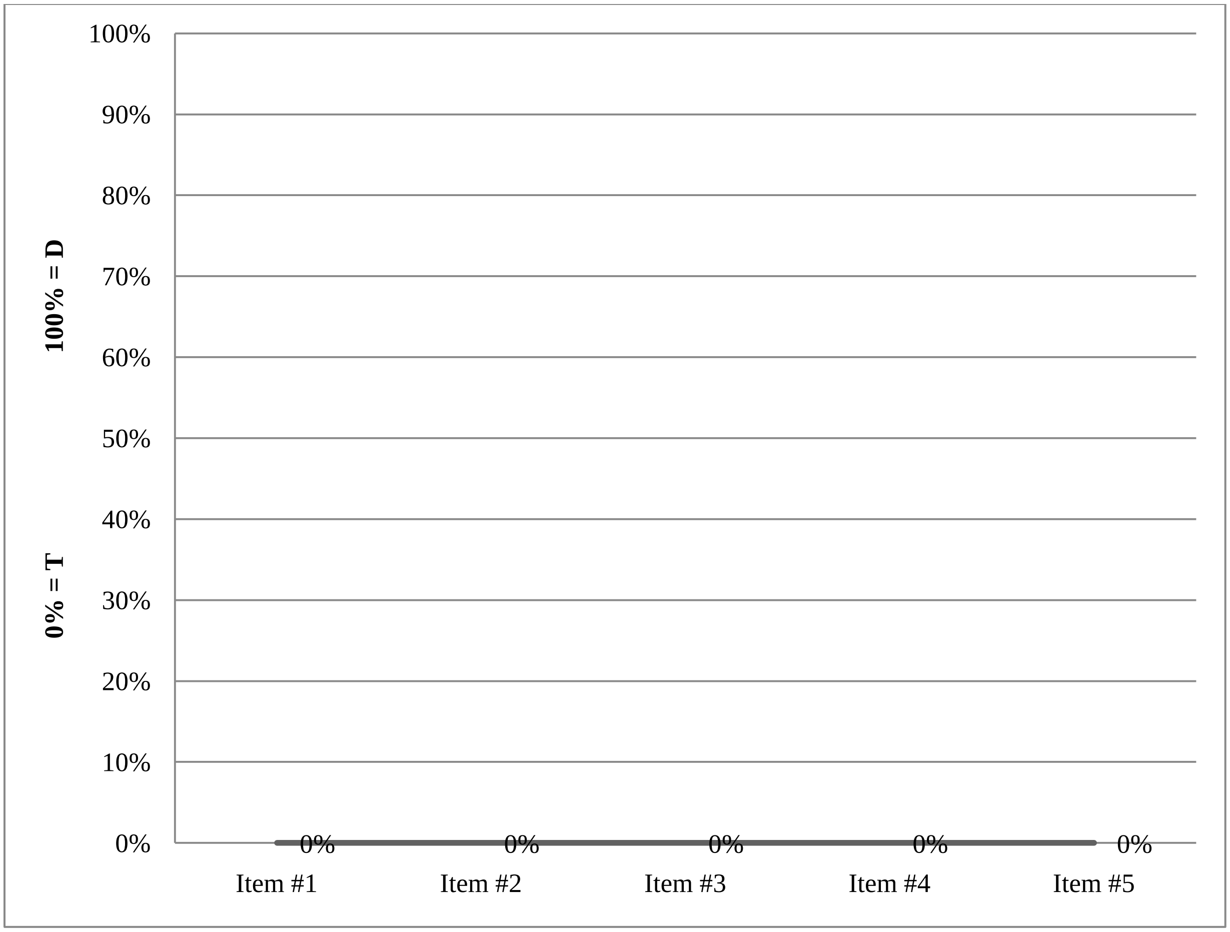


Figure 13 - Group A, Participant #10 Results

APPENDIX B - GROUP B INDIVIDUAL RESULTS

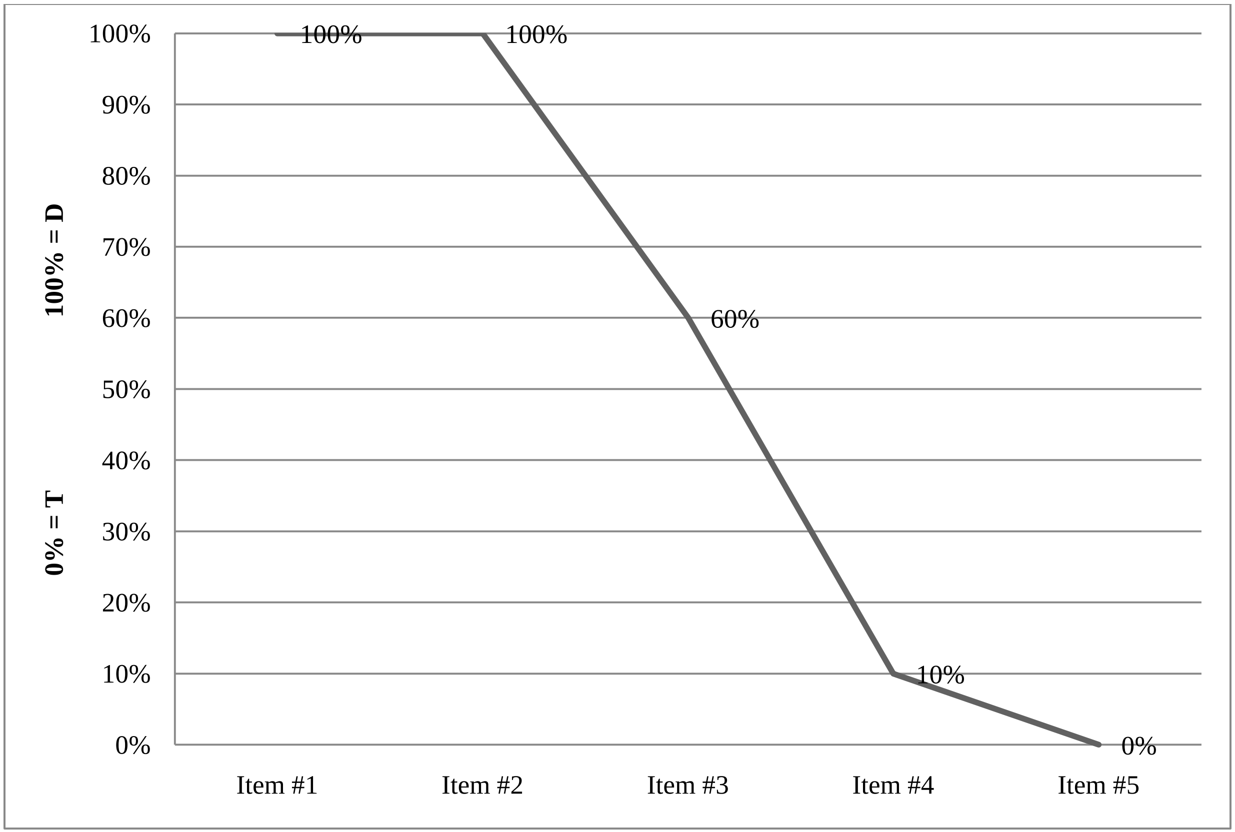


Figure 14 - Group B, Participant #1 Results

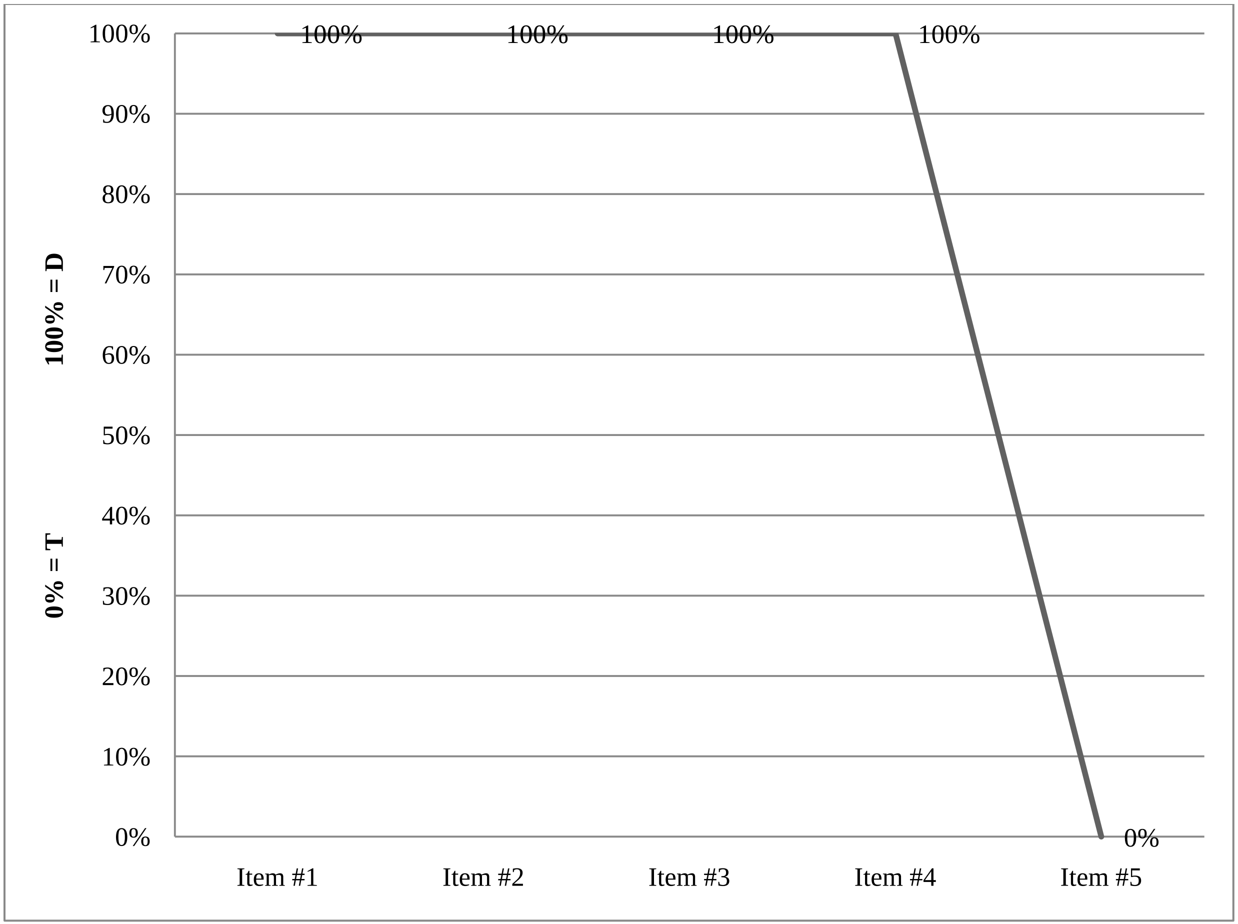


Figure 15 - Group B, Participant #2 Results

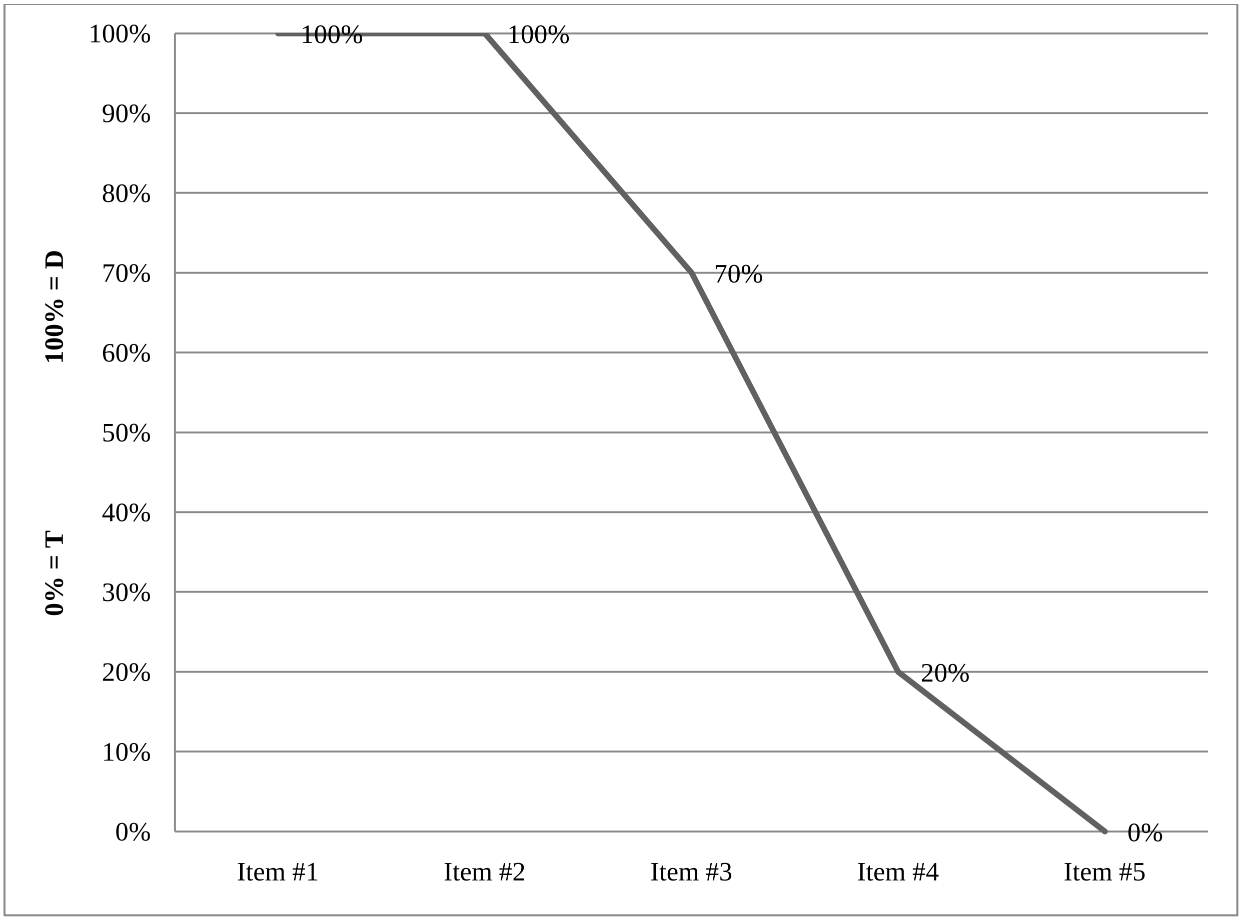


Figure 16 - Group B, Participant #3 Results

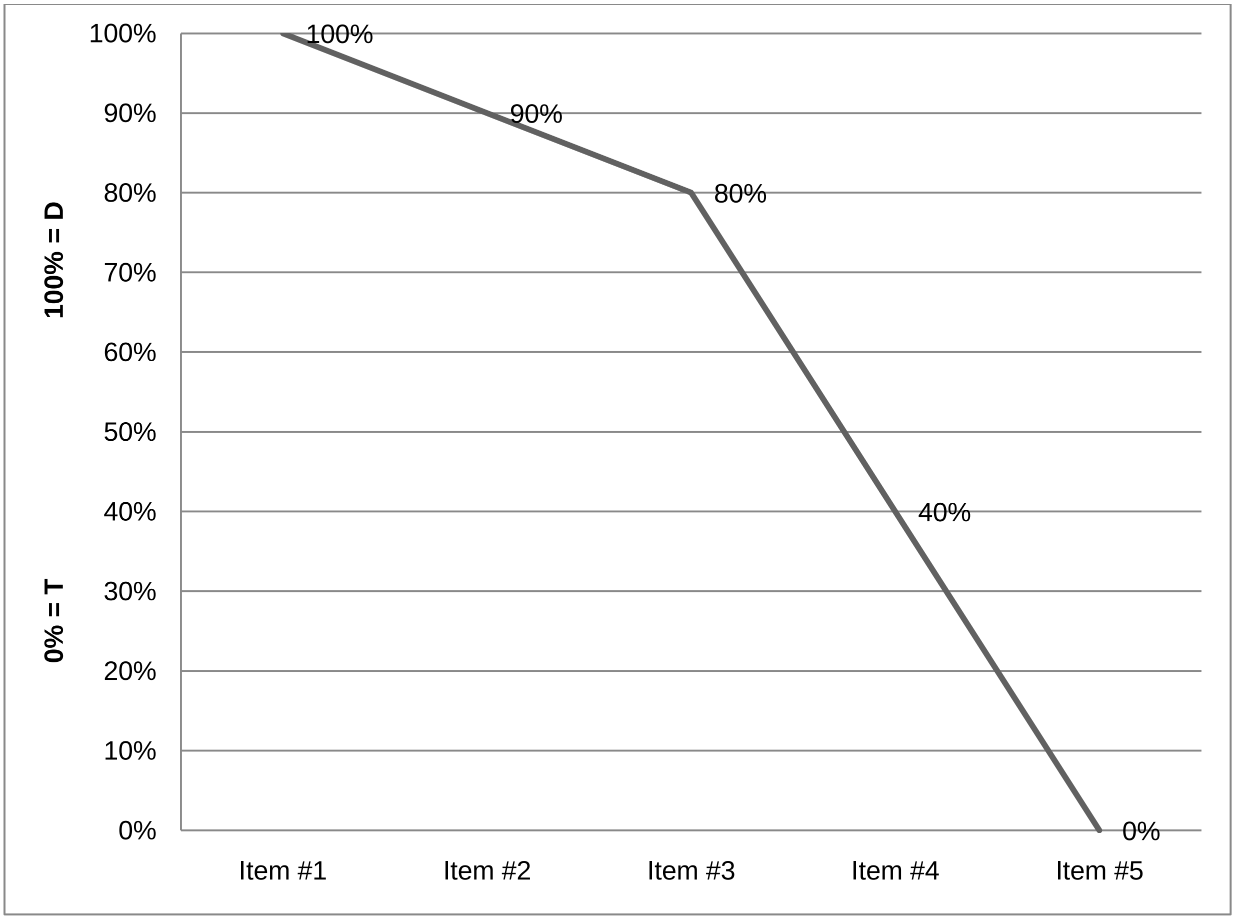


Figure 17 - Group B, Participant #4 Results

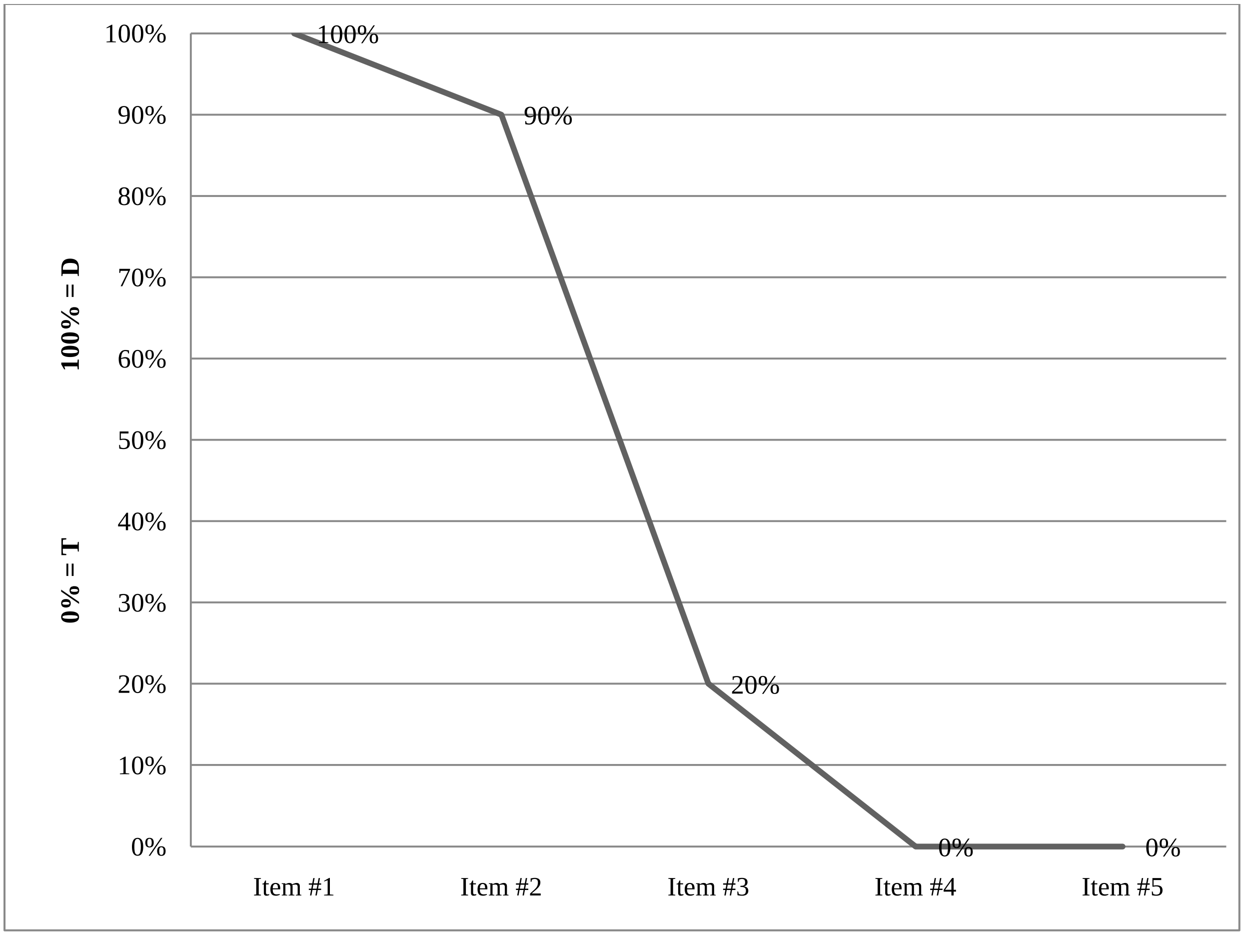


Figure 18 - Group B, Participant #5 Results

APPENDIX C - GROUP C INDIVIDUAL RESULTS

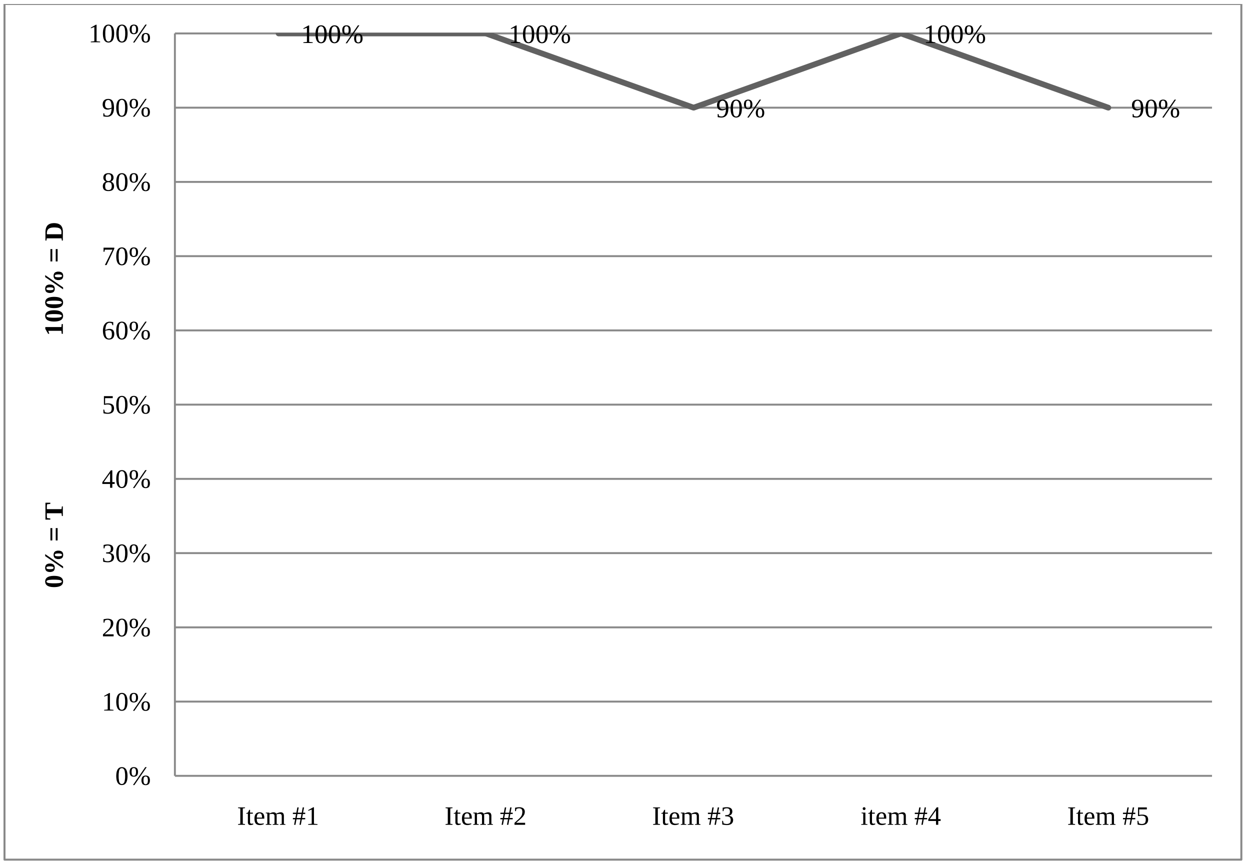


Figure 19 - Group C, Participant #1 Results

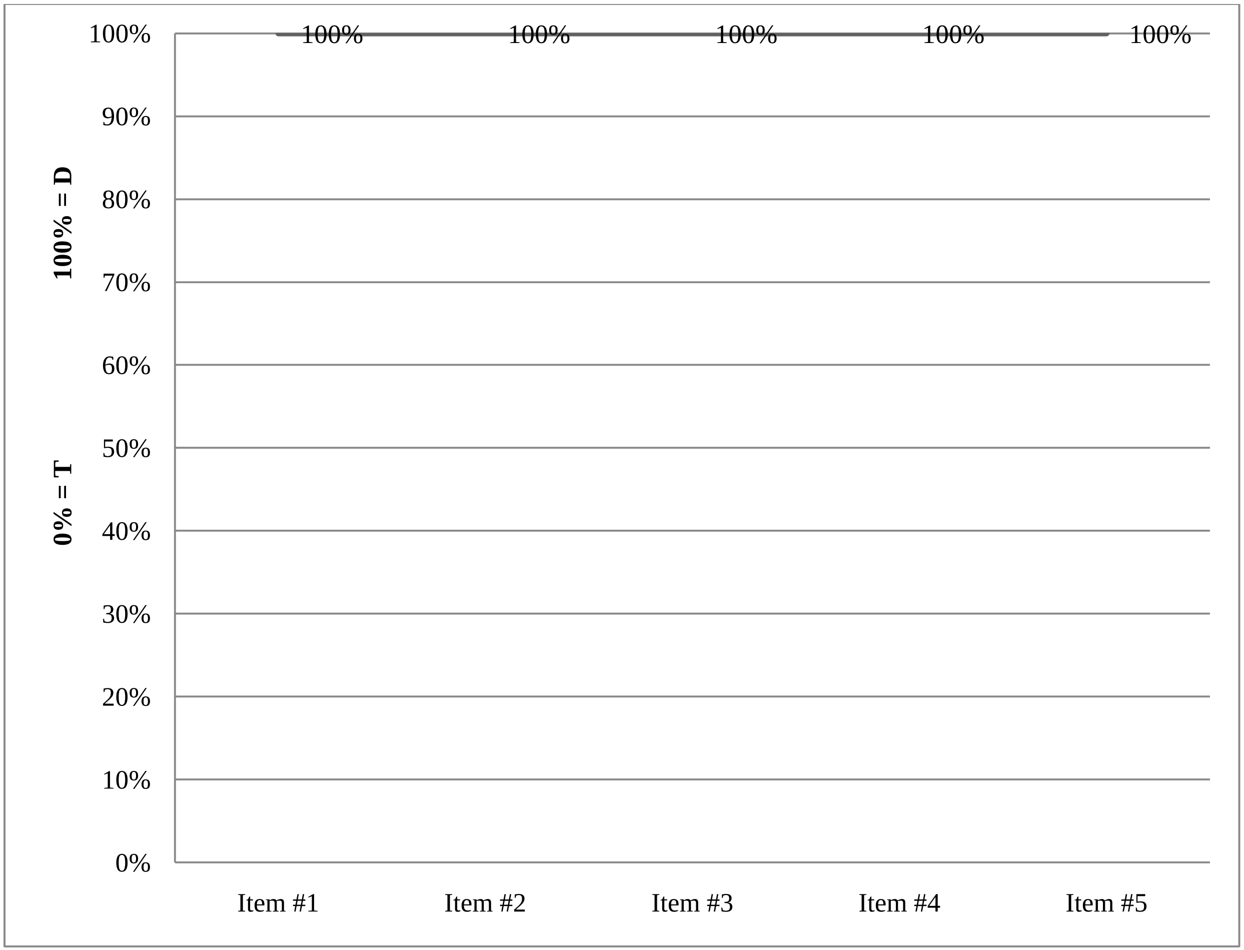


Figure 20 - Group C, Participant #2 Results

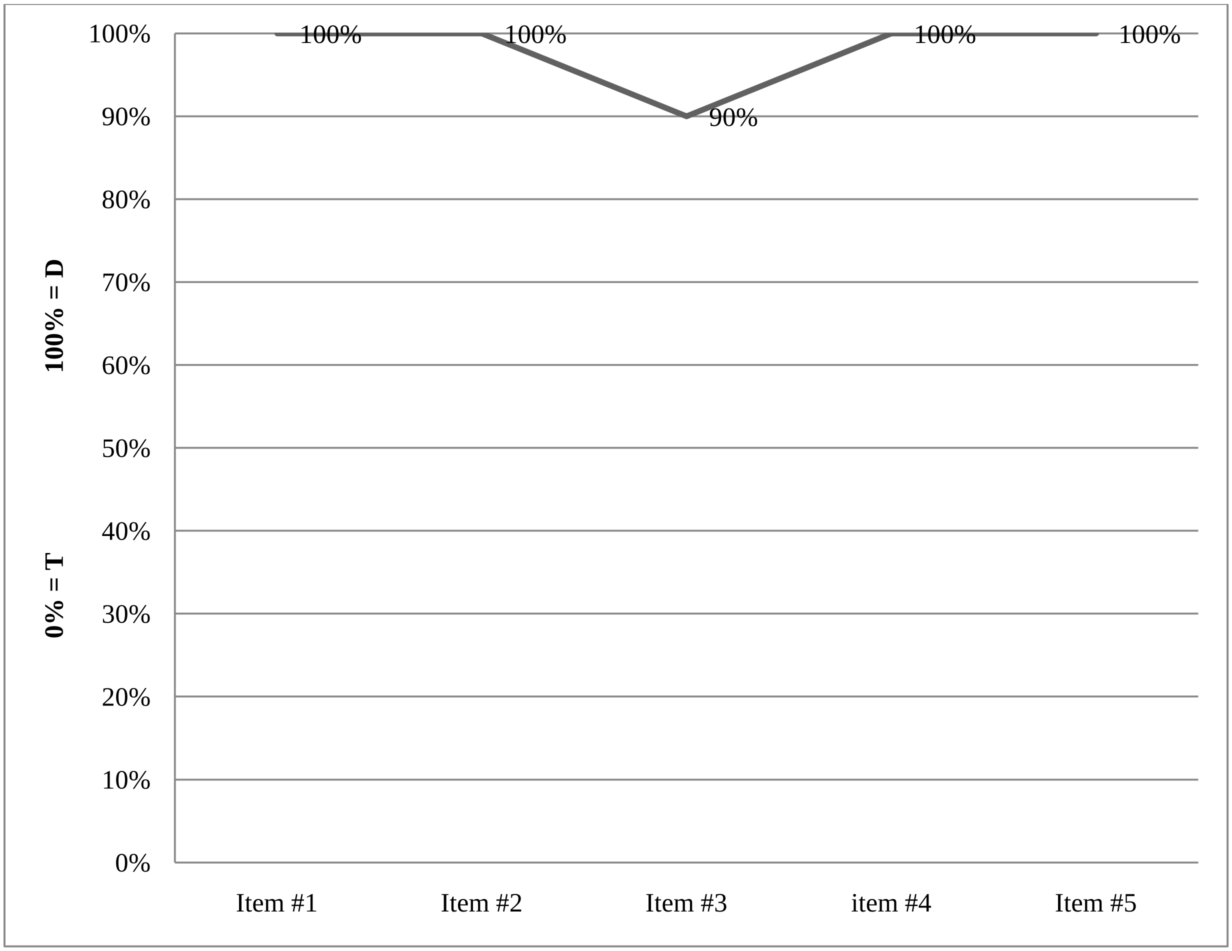


Figure 21 - Group C, Participant #3 Results

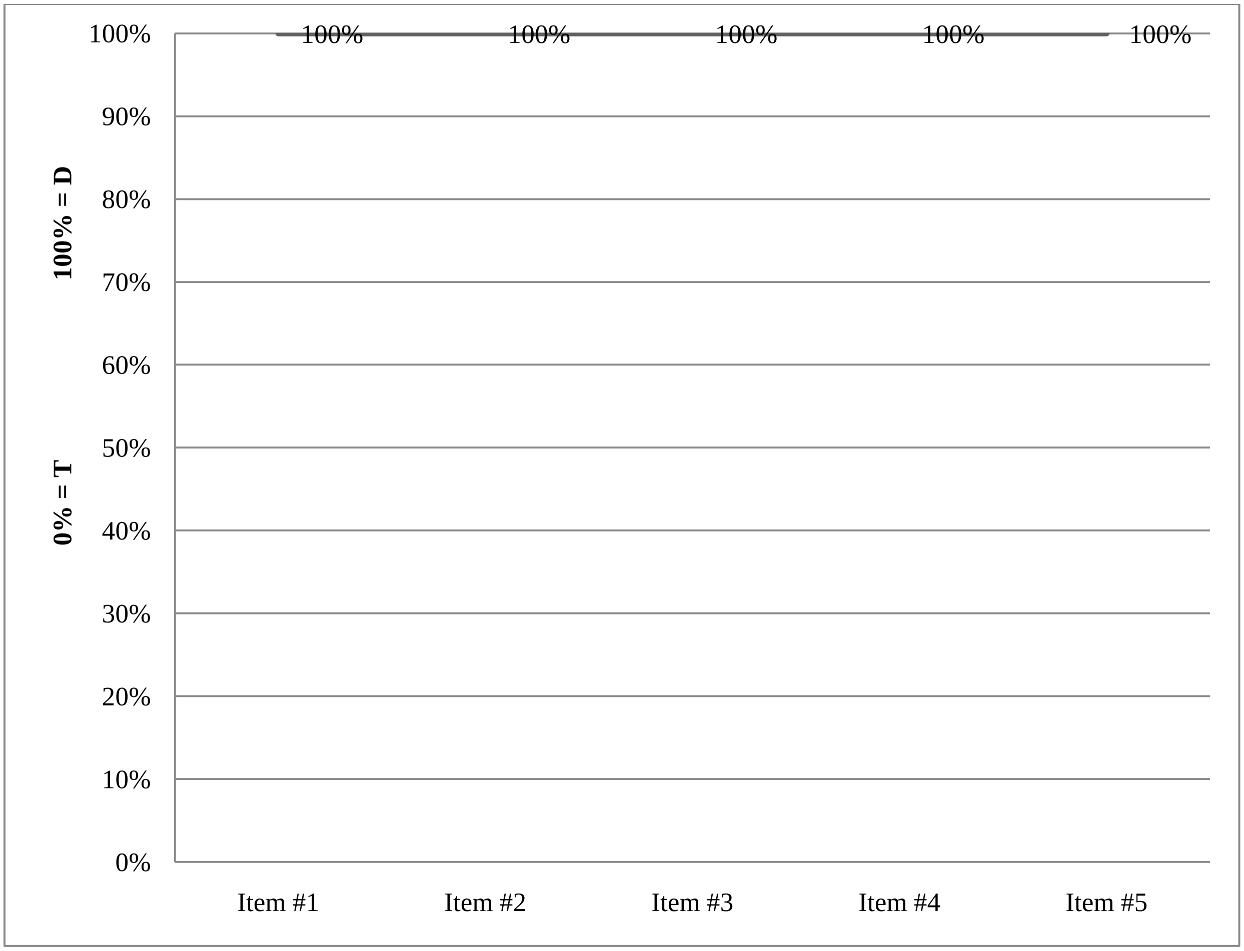


Figure 22 - Group C, Participant #4 Results

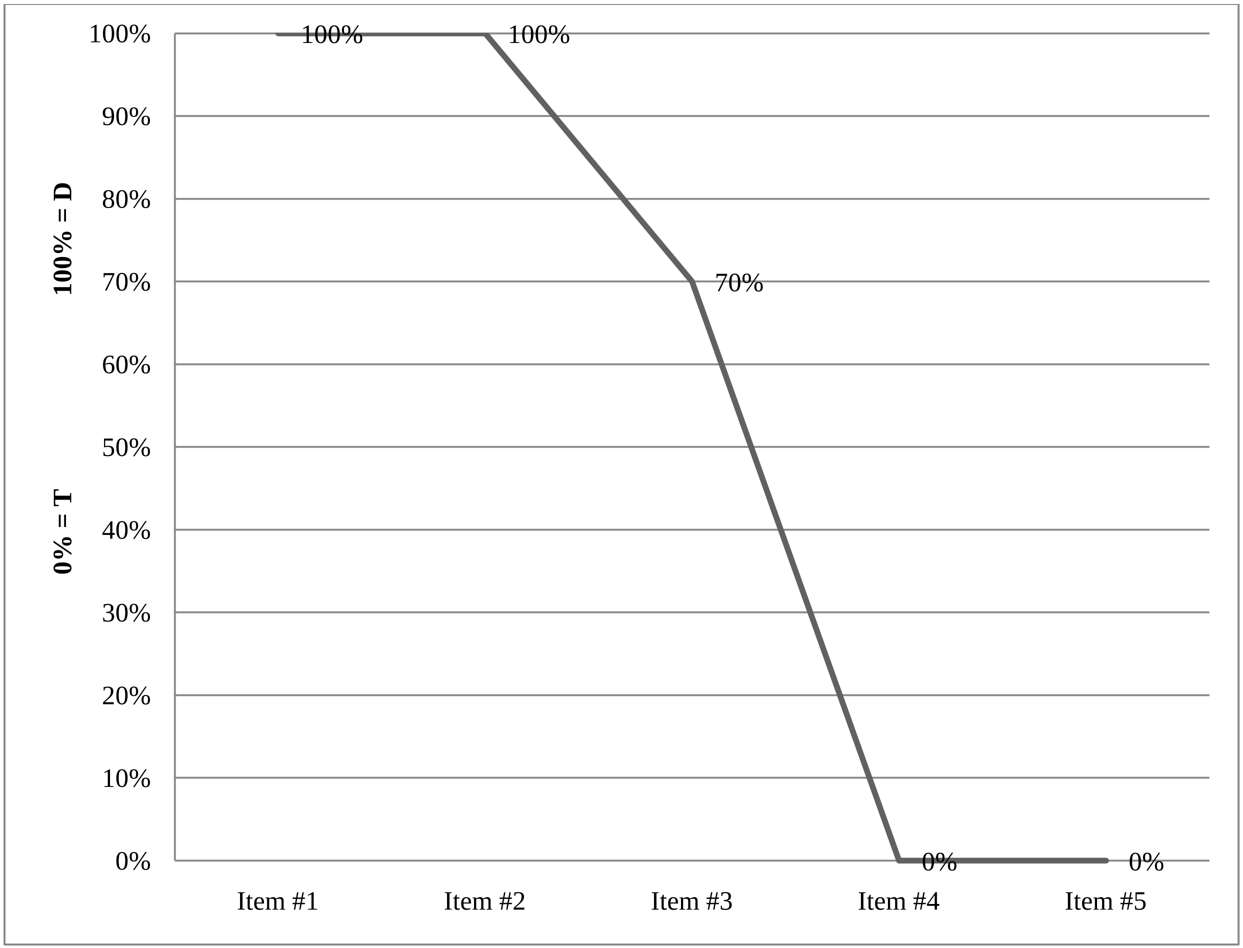
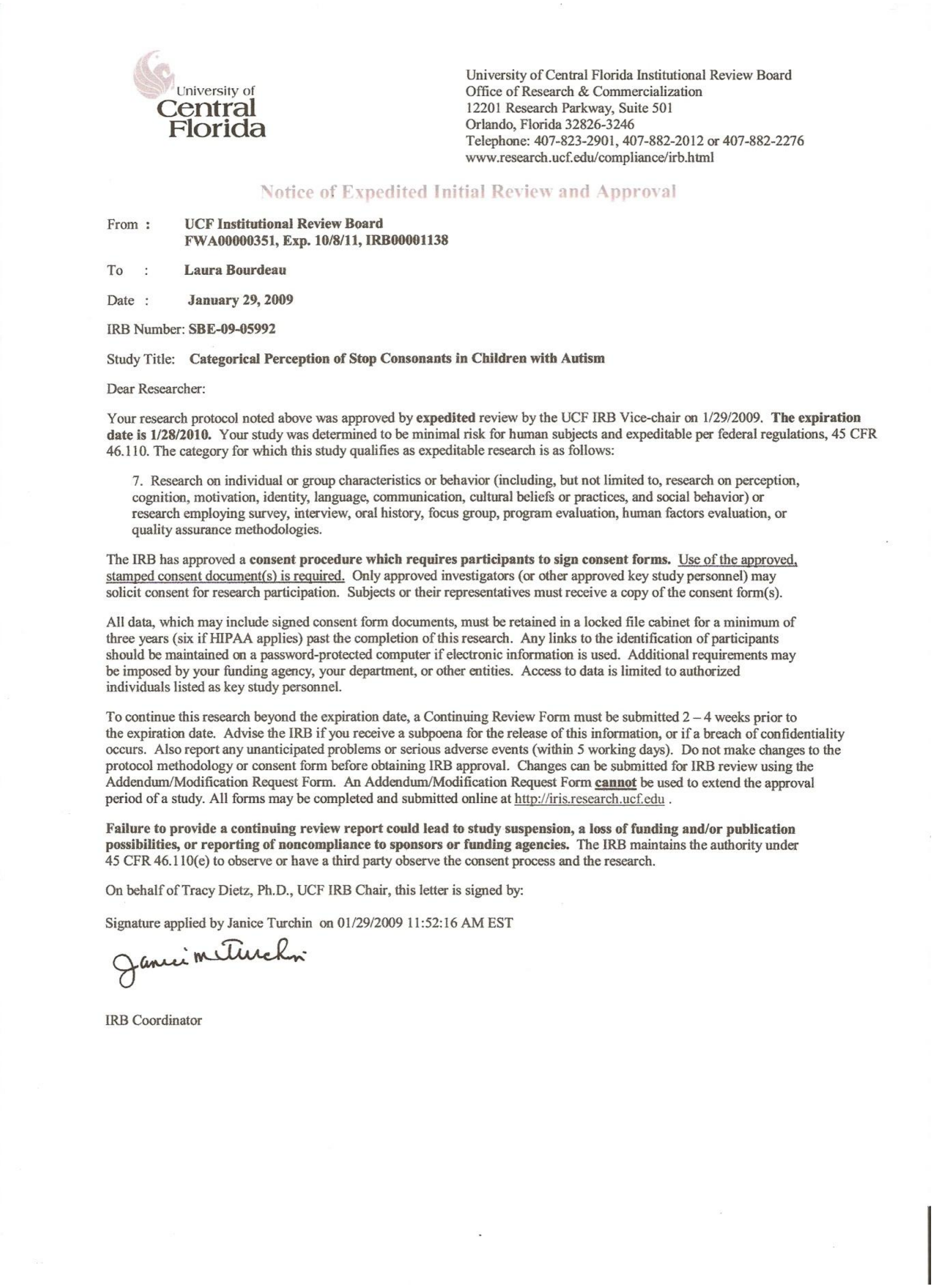


Figure 23 - Group C, Participant #5 Results

APPENDIX D – IRB APPROVAL LETTER



University of Central Florida

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901, 407-882-2012 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Notice of Expedited Initial Review and Approval

From : **UCF Institutional Review Board**
FWA00000351, Exp. 10/8/11, IRB00001138

To : **Laura Bourdeau**

Date : **January 29, 2009**

IRB Number: **SBE-09-05992**

Study Title: **Categorical Perception of Stop Consonants in Children with Autism**

Dear Researcher:

Your research protocol noted above was approved by **expedited** review by the UCF IRB Vice-chair on 1/29/2009. **The expiration date is 1/28/2010.** Your study was determined to be minimal risk for human subjects and expeditable per federal regulations, 45 CFR 46.110. The category for which this study qualifies as expeditable research is as follows:

> 7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

The IRB has approved a **consent procedure which requires participants to sign consent forms.** Use of the approved, stamped consent document(s) is required. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Subjects or their representatives must receive a copy of the consent form(s).

All data, which may include signed consent form documents, must be retained in a locked file cabinet for a minimum of three years (six if HIPAA applies) past the completion of this research. Any links to the identification of participants should be maintained on a password-protected computer if electronic information is used. Additional requirements may be imposed by your funding agency, your department, or other entities. Access to data is limited to authorized individuals listed as key study personnel.

To continue this research beyond the expiration date, a Continuing Review Form must be submitted 2 – 4 weeks prior to the expiration date. Advise the IRB if you receive a subpoena for the release of this information, or if a breach of confidentiality occurs. Also report any unanticipated problems or serious adverse events (within 5 working days). Do not make changes to the protocol methodology or consent form before obtaining IRB approval. Changes can be submitted for IRB review using the Addendum/Modification Request Form. An Addendum/Modification Request Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at http://iris.research.ucf.edu .

Failure to provide a continuing review report could lead to study suspension, a loss of funding and/or publication possibilities, or reporting of noncompliance to sponsors or funding agencies. The IRB maintains the authority under 45 CFR 46.110(e) to observe or have a third party observe the consent process and the research.

On behalf of Tracy Dietz, Ph.D., UCF IRB Chair, this letter is signed by:

Signature applied by Janice Turchin on 01/29/2009 11:52:16 AM EST

Janice m Turchin

IRB Coordinator

Figure 24 - IRB Approval Letter

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