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The Potential Influence of “Stimulus Overselectivity” in AAC: Information from Eye-tracking and Behavioral Studies of Attention

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Abstract

This paper examines the phenomenon of “stimulus overselectivity” or “overselective attention” as it may impact AAC training and use in individuals with intellectual disabilities. Stimulus overselectivity is defined as an atypical limitation in the number of stimuli or stimulus features within an image that are attended to and subsequently learned. Within AAC, the term “stimulus” could refer to symbols or line drawings on speech generating devices, drawings or pictures on low-technology systems, and/or the elements within visual scene displays. In this context, overselective attention may result in unusual or uneven error patterns such as confusion between two symbols that share a single feature or difficulties with transitioning between different types of hardware. We review some of the ways that overselective attention has been studied behaviorally. We then examine how eye tracking technology allows a glimpse into some of the behavioral characteristics of overselective attention. We describe an intervention approach, differential observing responses, that may reduce or eliminate overselectivity, and we consider this type of intervention as it relates to issues of relevance for AAC.

The Potential Influence of Stimulus Overselectivity in AAC: Information from Eye Tracking and Behavioral Studies of Attention with Individuals with Intellectual Disabilities

Some clinicians may have experienced the following: An individual who requires AAC demonstrates clear and reliable understanding of a symbol or a written word during assessment, but then seems to confuse that same symbol or word with others when they are integrated onto a larger AAC communication display or used in other situations. Clinicians may have also observed individuals who show unusual error patterns, such as choosing a seemingly quite-different symbol (such as a line-drawing for cherry) when presented with or

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requesting a particular item, (such as a pear). An oft-heard comment from parents and others when these patterns occur is: “But I’m sure you know that word!”

There are many possible reasons for these types of unreliable or uneven performances. Fatigue, changing medication, occurrence of seizures, or personal life events may lead to variability in attentiveness to or retention of learned information. Another, perhaps less well-recognized source of seemingly inexplicable errors may have to do with the features of the symbols themselves, and how those symbols are perceived by their viewers. Specifically, a phenomenon known as “stimulus overselectivity” or “overselective attention” may contribute to error patterns that are difficult to explain otherwise. This issue has been described from cognitive perspectives in terms of an overly narrow “spotlight” of attention, a deficit in broadening the spread of attention (e.g., Mann & Walker, 2003), a deficit in disengaging attention before shifting from one stimulus to another (e.g., Landry & Bryson, 2004), and as favoring local over global visual information processing (e.g., Porter & Coltheart, 2006). In this paper we will consider it from the perspective of behavior analysis, in which stimulus overselectivity is defined as atypically narrow attending to only a part of a stimulus or stimulus array, to the exclusion of the typical, broader examination of the entirety of the stimulus (a tendency to “fail to see the forest for the trees”). Within AAC, the term “stimulus” could refer to symbols or line drawings on speech generating devices, drawings or pictures in a Picture Exchange Communication System (Bondy & Frost, 1994), the elements within visual scene displays, or other types of AAC symbols, objects, and so forth.

An example of stimulus overselectivity from an educational perspective, is the problem of confusion of written sight words with similar spelling (such as push and pull; this example is expanded in the section below on overselectivity problems in special education). From the standpoint of AAC, apparent confusion of two otherwise distinct symbols such as *APPLE* and *PEAR* in the Mayer Johnson Picture Symbols (PCS; Mayer Johnson, 1992) may in fact reflect overselective attending only to the small stems at the tops of the pictures, rather than attending to the entire symbol. Overselective attending to a specific detail in an image may become an ever-greater problem as symbol vocabulary grows, as there becomes a greater and greater likelihood of overlap of one or more features across symbols in the display. Another relevant example of overlapping features in AAC symbols is offered by the PCS symbols representing emotion labels. Most or all of these contain elements related to facial features, and their meanings depend on the whole configuration of those features, rather than just one feature in particular. If an individual focuses on only one feature, and that feature appears on multiple of the faces, the likelihood of incorrect selection is quite high.

This goals of this paper are to (a) describe the ways in which stimulus overselectivity may affect learning and use of AAC by individuals who have intellectual disabilities, (b) raise the awareness of clinicians serving individuals who use AAC of the potentially important impact of overselectivity, (c) provide a brief review of behavioral research in overselectivity, (d) examine how research using eye tracking technology has revealed some of the behavioral characteristics of overselective attention, and (e) describe intervention approaches derived from research with relevance for AAC that reduce or eliminate overselectivity. We focus on individuals who have intellectual disabilities because the

problem of stimulus overselectivity in AAC occurs primarily in this population, as explained below in the section on current definitions of overselectivity.

Overselectivity has been discussed by some authors in relation to AAC, although most often in the context of other questions such as literacy, perceptual cues, or sign language instruction (Chiang & Carter 2008; Remington & Clarke, 1993a, 1993b; Schlosser & Blischak, 2004; Wilkinson, Carlin, & Thistle 2008; Wilkinson & Reichle, 2009). There has been little direct study of this issue within the AAC field. However, the phenomenon has received study in the discipline of behavior analysis, both from the perspective of error analyses of discrimination learning tasks that suggest overselectivity, as well as in detailed analysis of eye-gaze patterns (measured through eye tracking research apparatus) that demonstrate limited observing and scanning of stimuli. These two lines of research, defined and described in detail in the following sections, suggest directions for interventions to reduce overselectivity and its resulting errors.

Stimulus Overselectivity and Individuals with Intellectual Disability

This paper addresses stimulus overselectivity in individuals who have intellectual disabilities, although some of the reviewed research includes individuals without disabilities. The problem has been widely studied within the “discrimination-learning” perspective of behavior analysis and experimental psychology. Discrimination learning refers to the process by which individuals learn to make different responses to different stimuli, usually on the basis of differential feedback for responses. Thus, for instance, individuals are often provided choices via AAC symbols; they might select between symbols for two activities (playing on the *IPAD* versus listening to the *RADIO*), two locations (*PLAYGROUND* versus *GYM*), or two snacks (*CHIPS* versus *COOKIE*). Access to the chosen option after selection is the feedback, that is, the reinforcer for the behavior of selecting it. On the basis of this feedback, discrimination learning can occur, such that the individual reliably selects between the two symbols and demonstrates behavior consistent with that choice upon receipt of the feedback (satisfaction at receiving the chosen item, independent selection of the item after symbol use, etc).

When the characteristics of an individual stimulus or of the broader environment around an individual influence that individual’s behavior, the stimuli/environment are said to exert “stimulus control.” Stimulus control can be observed in any number of everyday experiences. When anticipating a planned incoming phone call, one does not lift the telephone receiver at random intervals; rather, the behavior of lifting the receiver is contingent upon hearing the ringtone. Thus, the “receiver-lifting” behavior is under the stimulus control of the ringtone. More directly related to AAC, Reichle and colleagues (Reichle, Dropik, Alden-Anderson, & Haley, 2008; Reichle & McComas, 2004; Reichle et al., 2005) conducted a line of research on the conditional use of requests for assistance by individuals with severe disabilities who use AAC. Specifically, they examined methods for teaching not just the behavior of requesting assistance, which is valuable, but the also-valuable behavior of not requesting assistance when the task could be completed independently. Independent performance was promoted by making the reinforcer equal or more valuable for an independent act than for an act that had been preceded by a request for

assistance. While this intervention was focused on the effect of the feedback (reinforcers), it necessarily required antecedent stimulus control by aspects of the environment, in particular the task conditions (easy/hard), as the learner had to distinguish between conditions under which the act of requesting help was needed versus conditions under which independent performance was possible.

Overselectivity is seen as an atypical limitation in the number of stimuli or stimulus features to which learning occurs, with the result that stimulus control is unusually narrow and restricted. For example, the Mayer Johnson PCS symbol for *TENNIS* shows a gray racquet with a yellow ball. Typically, discrimination training for selecting this symbol when given the spoken cue, such as the auditory input *tennis*, will result in stimulus control by the entire symbol (i.e., the racquet-and-ball as a compound stimulus). However, if overselective stimulus control were restricted to the ball only, and the student had learned to identify the symbol on the basis of that one isolated feature alone, then the student may make errors during subsequent symbol use when the symbol *BALLOONS* is present because that symbol includes a yellow balloon about the same size and color as the tennis ball.

Similar problems could be imagined in terms of upgrades in software or hardware that alter visual aspects of a device or its display, or in changes from one form of technology to another as an individual's needs change over time. For instance, consider an individual who is using a device functionally, able to turn it on and navigate through the symbol displays. That individual may have overselective attention to a feature, perhaps attending to some small feature located on the power button (even something as irrelevant as a scratch or bump on the button). As long as that feature is present, there are no negative consequences for the overselective attending. However, if the device is upgraded or returned to the manufacturer temporarily and that irrelevant but overselectively-attended feature is absent on the new or replacement device, functional use could be affected. An individual who previously appeared to demonstrate operational competence might now appear to be floundering, not because she or he forgot how to turn on a device, but because the feature that signaled to that individual where the power button was (the discriminative stimulus) is no longer present.

Early Studies of Overselectivity

During the early 1960's, Dr. O. Ivar Lovaas and colleagues were among the first to apply the methods of behavioral psychology to the treatment and education of children diagnosed with autism. The goals of their program were to establish communication and to decrease maladaptive behavior. It is sometimes underappreciated that Lovaas's initial research interest was in developing better methods for teaching children with language delays, and in the effects that improved communication skills might have on other areas such as social interaction (Smith & Eikeseth, 2011). Children with autism were chosen as the study population because of their social and communication deficits. One aspect of these children's behavior was described as follows:

Operationally, our data show that when autistic children are presented with multiple stimulus inputs, their behavior comes under the control of a range of input that is too restricted. This problem was referred to as 'stimulus overselectivity'

(Lovaas, Schreibman, Koegel, & Rhem, 1971) because the children overselected a limited number of stimuli from those available in their environment (

Lovaas, Koegel, & Schreibman, 1979, p. 1237).

The experimental methods used by Lovaas and others most often involved initial training with stimuli that contained multiple elements (for instance, ABC, which contains three different letters) followed by testing with the individual elements (for instance, A alone). The goal was to determine the breadth of learning. Initial training usually offered repeated choices between two multi-element stimuli. For example, a multi-element stimulus ABC might be presented alongside XYZ, with the stimulus ABC designated as the correct choice for all trials (and XYZ always incorrect). After participants reliably selected ABC on every trial, tests presented the various combinations of individual elements, A vs. Y, B vs. X, etc. When given such tests, school-aged children with typical development are highly likely to respond correctly to all combinations of elements, but children with developmental disabilities may respond to only a subset of elements (Wilhelm & Lovaas, 1976). These results indicate that the children with developmental disabilities had learned to perform the ABC vs. XYZ task on the basis of only one or two of the stimulus elements (e.g., on the basis of A or B, but not C).

Current Definitions of Overselectivity

The initial experimental studies that defined the problem of stimulus overselectivity in children with developmental disabilities have been reviewed in Lovaas, Koegel, and Schreibman (1979), and the literature since that time has been summarized in recent reviews by Ploog (2010) and Brown and Bebko (2012). Overselectivity has been found in visual, auditory, and tactile stimulus modalities.

Perhaps because of Lovaas and colleagues' study population, overselectivity is often associated with autism. While it is certainly observed in individuals with autism, it is also observed in individuals with intellectual disabilities who have not been diagnosed on the autism spectrum. For example, Dickson, Wang, Lombard, and Dube (2006) assessed overselectivity in students at residential schools for individuals with developmental disabilities. Overselectivity on at least one test occurred in 43% of those participants who did not meet the Autism Diagnostic Observation Schedule (ADOS) diagnostic criterion for a classification of autism. Overselectivity has also been reported in school-aged children with learning disabilities but no intellectual disability (Bailey, 1981) and in children with hearing impairment and concomitant difficulties with communicative competence, as reported by a speech pathologist, audiologist, and/or classroom teacher (Fairbank, Powers, & Monaghan, 1986).

Although there is considerable variability among studies in the methods, the literature indicates inverse relations between the prevalence and severity of overselectivity and intellectual level, as expressed on standardized IQ scores, and developmental level, as expressed in mental age equivalence scores. As an example of the latter, Dickson, Deutsch, Wang, and Dube (2006) reported the results of overselectivity assessments using matching-to-sample methods with multi-element stimuli (procedure description below) in 70 individuals attending residential special-education schools. Before the test for

overselectivity, participants were given preliminary tests to evaluate prerequisite performances such as accurate matching with single-element stimuli. Twenty-one of the 70 participants failed the pre-tests and the mean Peabody Picture Vocabulary Test - Revised mental age equivalent (MEA) score for these individuals was 3.70 years. Results indicated overselectivity for 35 participants and mean MAE for this group was 5.28 years. Finally, the results showed no overselectivity for 14 participants with mean MAE of 7.44 years. Thus, MAE scores were related to both matching-to-sample performance and stimulus overselectivity.

Overselectivity Problem Areas in Special Education

One problem associated with overselectivity in special-education settings is sometimes referred to as “prompt dependency” (Hume, Loftin, & Lantz, 2009; MacDuff, Krantz, & McClannahan, 2001). While teaching, it is sometimes useful to provide supplemental cues to prompt new learning. For example, a teacher might model the use of an AAC device, or point to the correct alternative during initial stages of teaching. When prompts are used, they must at some point be withdrawn. If the student has attended only to the prompt (e.g., the teacher’s pointing finger) and not to the teaching materials (e.g., the AAC symbol), then errors will occur when those prompts are no longer present (e.g., Schreibman, Charlop, & Koegel, 1982). The body of research by Reichle and colleagues on promoting independent acts and the conditional use of requests for assistance, described in an earlier section, represents one means of minimizing reliance on prompts.

Some problems in the acquisition of language and communication skills may be related to overselectivity in responses to auditory (speech) or visual (e.g., printed words) cues (e.g., Koegel, Schreibman, Britten, & Laitinen, 1979; Schreibman, 1997). Dube (2009) describes some examples of this type of problem from special-education classrooms. In one instance, a student was learning to read sets of printed words aloud, with new words added individually to an expanding set. Progress was good as exit, men, walk, and push were learned. The fifth word was pull. As soon as it was introduced, naming accuracy fell, and almost every error was saying *push* when pull was presented. After several sessions, the student also began to say *pull* on some trials when push was presented. In subsequent sessions, the teachers sometimes eliminated one or the other of these words, push or pull, but accuracy did not improve. Finally, after 15 sessions, both push and pull were dropped. Accuracy recovered immediately, and there were no problems as the new word sun was introduced. Later, however, when the word mug was introduced, accuracy once again fell due to errors saying *men* when mug was presented. Apparently, the learning was overselective in that it was restricted to the initial letters of the words. It is noteworthy that the problem went undetected at first, until circumstances changes so that the overselected cue was present in more than one word.

The Matching to Sample Task and Overselectivity

Many of the studies of overselective attention in individuals with developmental disabilities use what is called a matching-to-sample paradigm. The use of matching to sample to study overselectivity in individuals with developmental disabilities began to increase approximately 30 years ago (e.g., Mackie & Mackay, 1982; Schneider & Salzberg, 1982;

Whiteley, Zaparniuk, & Asmundson, 1987). To evaluate overselectivity by matching-to-sample methods, trials begin with the presentation of multi-element or multi-dimensional *sample* stimuli. Thus, a participant might see a sample such as AB presented on a computer screen. After an observation period, the sample is removed from view and an array of *comparison* stimuli follows immediately. At first, the target comparison may be identical to the sample and there are no overlapping features among the comparison elements; so if the sample were AB, the choices among the comparisons might be AB, CD, and EF, with the identical AB as the target choice. Note that on such trials, correct responding is possible even if the participant is overselectively attending to just one element of the sample. A participant who attended only to the second element, for example (the B) is able to select correctly, even without having attended to the full stimulus.

The tests for overselectivity include trials in which only one of the individual sample elements (or a subset of them) is presented. For example, on some trials the comparison displays may consist of only A, C, and E and on other trials the comparisons are B, D, and F. On trials with sample AB, a participant who overselectively attended only to the B will perform at chance levels on the first type of trial (which presented A, C, and E) but with high accuracy on the second (which presented B, D, and F). Such a pattern indicates overselective responding to sample element B.

Eye Tracking Research and Understanding Stimulus Overselectivity

Although the results of studies using matching-to-sample procedures may indicate that individuals with intellectual disabilities demonstrate stimulus overselectivity, these procedures do not illuminate the processes underlying overselectivity. Eye tracking research has provided new insights into this issue by direct measurements of observing behavior while individuals perform matching-to-sample tasks. This section describes two studies from the eye tracking laboratory at the University of Massachusetts Medical School's Shriver Center for research in intellectual and developmental disabilities. These studies used matching-to-sample procedures to study visual stimulus overselectivity as it may occur with arrays of discrete forms. Although the tasks described in this section do not generally resemble the communication tasks faced by individuals who use AAC, the key take-away point to be made is that these studies can help in understanding the phenomenon of overselective attention itself. As we describe in the following section, such an understanding can in turn be used to help build interventions that do not require eye tracking research technology, but that can reduce the interference of overselectivity on behaviors that include learning and selecting symbols on an AAC display.

Behavior and Eye Tracking Research: Measuring Overselectivity

The first study, Dube et al. (2010), illustrates two primary points: First, overselectivity in individuals with intellectual disabilities need not indicate a deficit in the capacity for attention. Second, there is a useful distinction to be drawn between observing behavior (Dinsmoor, 1985) and the covert/internal process of attending. Although the terms are somewhat broader, the distinction between observing behavior and attending is largely parallel to the somewhat more specific distinction made within eye tracking research between "fixation" and "visual attention." That is, as Wilkinson and Mitchell in this issue

(2014) review, the presence of a fixation to a stimulus as recorded through eye tracking research apparatus is necessary but not sufficient to ensure that the stimulus has been attended to and forwarded for further cognitive processing. Thus, in some instances a stimulus receives a fixation, but the individual demonstrates no behavioral indication of having attended to it (e.g. they later report not having seen it, or fail to identify it). In behavioral psychology, the term “observing behavior” for visual stimuli includes not only the fixation itself, but also behavior such as changes in head and eye orientation that may accompany the fixation. The occurrence of observing behavior as reflected through fixations can be measured directly by an eye tracking research apparatus.

In contrast to observing behavior, “attending” is measured indirectly, by some explicit behavioral response that verifies discrimination (processing) of the relevant stimuli. That is, there is a distinction between mere gaze fixation, and attention at the level of cognitive engagement. For example, if an eye-tracking research participant were asked to identify a word displayed on a computer screen, *observing* the word could be verified by eye-tracking data showing that the focus of the individual’s gaze was on the letters that make up the word. Verification of *attending* to the word, however, requires additional behavior such as reading the word aloud, typing the same word on a keyboard, or something similar.

Dube et al. (2010) illustrated the distinction between observing behavior and attending. The test procedure in this study was matching to sample with two-element sample stimuli. The test was presented on a touch-screen computer monitor and the eye tracking research apparatus was ISCAN RK-426PC Pupil/Corneal Reflection Tracking System, RK520PC Autocalibration System, and Miniature Head-Mounted Eye Imaging and Line-of-Sight Scene Imaging Systems¹. Preliminary testing verified that participants could perform the task with high accuracy (> 90%) when the sample stimuli were single stimuli (e.g. on a trial with the sample A and comparisons A, B, and C, all participants could reliably select comparison A). These tests verified an understanding of the task, accurate discrimination within the stimulus set to be tested, and adequate motivation.

The structure of the test trial is illustrated in Figure 1. Test trials began with two sample stimuli presented in the center of the computer screen (Figure 1, Panel A). The duration of the sample observation period was determined by the participant, who was free to observe the sample(s) for as long as she or he chose. When the participant touched the sample display area with a finger (Panel B), the samples disappeared and three single comparison stimuli were presented immediately in three corners of the screen (Panel C; this procedure is called zero-second delay identity matching). As Figure 1 illustrates, the correct comparison matched one of the samples and the other two comparisons matched neither sample; one of the samples had no matching comparison. The sample stimulus in the left or right position appeared in the comparison array on an equal number of trials, and so the participant could not predict which of the samples would subsequently be the correct comparison. Sessions consisted of 36 trials, and different stimuli appeared on all trials, drawn at random from a pool of 180 non-representational forms like those shown in Figure 1.

¹ISCAN Inc., 21 Cabot Rd., Woburn, MA 01801.

The two-sample test was administered to four adults without disabilities and 10 individuals with mild to moderate intellectual disabilities. For all of the adults without disabilities and 4 of the 10 individuals with intellectual disability, high accuracy scores ($> 90\%$) indicated no overselectivity. They were able to match either of the sample stimuli on almost every trial. The reliably correct matching responses were the behavioral measure that verified observing and attending. Observing was confirmed by the eye tracking data showing visual fixations of both sample stimuli on virtually every trial and mean observing durations ranging from 0.34 to 1.18 s per stimulus per trial.

For six of the individuals with intellectual disability, intermediate accuracy scores (53% to 78%) indicated stimulus overselectivity. The reason that this intermediate accuracy reflects overselectivity follows from the logic outlined previously. In this case, the sample consisted of two stimuli (e.g., AB) and the choice array contained three stimuli, one of which matched one of the samples (e.g., A, C, E on some trials, and B, D, F on others). Overselective attending to A would result in approximately 100% correct responding when the array contained A, but chance levels (33%) when the array contained B. With both types of trials equally represented, the mean overall accuracy score would be approximately 67% (see Dickson, Deutsch, et al. 2006 for further details of the accuracy score analysis).

The eye-tracking data for these participants showed that the great majority of errors occurred on trials when the participant fixated on only one of the two sample stimuli. These failures to observe one of the samples occurred on 32% to 60% of the trials across participants. Other errors on a smaller number of trials followed relatively brief observing durations (< 100 ms). Data analysis showed that the overselectivity was closely linked to inadequate observing behavior. On the subset of trials on which only one sample stimulus was observed and that stimulus was also the correct comparison, mean accuracy for the six participants was 98%; on the trials with only one sample observed and that stimulus was not included as a comparison, mean accuracy was 33% (chance level). The overall intermediate accuracy scores resulted from averaging these two types of trials. When observing occurred, attending was reliable.

Behavior and Eye Tracking Research: Observing Duration and Behavioral Flexibility

A second eye tracking study, Dube et al. (2006), further illuminates the issues of observing and attending. This study includes data on the relation between two different aspects of observing that are relevant to AAC instruction: eye movements while observing the stimuli within an array, and other behavior that ends the opportunity to observe. The latter is often a manual response to the device displaying the stimuli. For example, when selecting a symbol from an AAC array, the individual first scans the array to locate the symbol. Upon manual selection of the target symbol, the scanning period is terminated. As the number of stimuli in the display changes, optimal performance requires flexibility in both the trajectory of the scanning behavior and the timing of the selection response.

In Dube et al. (2006), four adults without disabilities were tested with the same matching-to-sample procedure described above and shown in Figure 1: At the beginning of each trial, two sample stimuli were presented and remained displayed until the participant touched the

screen. Then the samples disappeared and the comparison stimuli were presented. Different stimuli appeared on every trial. All four had high accuracy scores (96% to 100%).

Next, the number of samples was suddenly increased from two to four per trial. Accuracy scores remained high for two participants (92%) but fell to intermediate levels for two others (63% and 67%). Thus, overselectivity was temporarily (see below) provoked in participants without disabilities by an abrupt increase in task complexity.

Eye-tracking analyses of the first session with four-sample trials showed that all of the participants made similar numbers of observations per trial (6 to 8 stimulus fixations) and there were very few failures to observe one or more of the stimuli. The difference between participants with high versus low accuracy was in the sample-stimulus observing durations. The high-accuracy participants spent more than twice as long observing the four stimuli as they had observing two, with increases from means of 1.24 s to 3.65 s per trial for one participant and from 1.70 s to 4.19 s for the other. In contrast, the increases for the participants whose accuracy declined to overselective levels were much smaller, from 2.53 s to 2.66 s for one participant and from 1.32 to 2.02 s for the other. These participants then practiced with the four-sample task until accuracy scores rose to 100% (practice required 36–108 trials). Eye tracking data showed that the now-accurate performance was accompanied by relatively small changes in the number of fixations per trial, but large increases in sample-stimulus observing durations for both participants (from 2.66 s to 6.59 s per trial for one, and from 2.02 s to 4.12 s for the other).

These results suggest that different aspects of observing behavior may be independent. For subjects with high accuracy on the initial four-sample test, increases in both the number and duration of stimulus observations were approximately proportional to the increase in the number of sample stimuli. For those subjects with low accuracy on the initial four-sample test, the number of observations increased proportionally, but the total time spent observing did not. After the practice that re-established high behavioral performance, the total time spent observing was measurably greater as well.

The apparent inflexibility in observing duration is consistent with basic laboratory research showing that observing behavior may be resistant to change when the stimuli that are observed are correlated with high rates of reinforcement (e.g., Shahan, Magee, & Dobberstein, 2003). One implication for teaching AAC is that some students may need explicit training to pace scanning behavior in relation to the number of individual stimuli to be examined (e.g., AAC symbols), rather than some other global aspect of the displays.

Training Broader Attention: Prompting Observing Behavior

Five of the six participants with overselectivity in Dube et al. (2010) were given interventions designed to improve observing behavior during the eye-tracking sessions (one participant dropped out of the study because he was uncomfortable with the eye tracking research apparatus). These interventions occurred during the sample observation period, and they included various types of prompts; sometimes it was necessary to try several different types of prompts before finding one that was effective for each participant. Because these prompts changed some feature(s) of the experimental stimuli or introduced new stimuli, they

are examples of a stimulus-based intervention approach. For one participant, the effective intervention was standard pointing prompts with verbal instructions while the experimenter pointed to sample stimuli (e.g., *Look at this one, now the other one, now the first one again...* etc.). The eye tracking research apparatus produced a video image showing the participant's field of view with a superimposed cursor indicating the current point of gaze. The cursor position was continuously updated. This composite image was displayed to the experimenter on a monitor. The experimenter was therefore able to watch this monitor while prompting to verify compliance with the prompts. The participant's accuracy score increased from 53% to 88% in the first session with the pointing prompt (Dube et al., Table 5, Participant MAR).

Another successful prompting technique was "within-stimulus" prompts, so-called because the prompt involved an internal feature of stimulus itself -- as opposed to the pointing finger, which was next to the stimulus and would be termed an extra-stimulus prompt (cf., Schreibman, 1975). These within-stimulus prompts included sudden changes in size and/or color of the sample stimuli. The rationale was that a series of abrupt changes in salience difference between the sample stimuli may capture fixation and attention (Yantis, 1996). During the prompting sequence, the touchscreen was de-activated so that the participant's touch did not terminate the sample observation period. When the prompting sequence was complete, the touchscreen became active and the trial proceeded. It is notable that the notion of using these types of motion-based prompts has been discussed as potentially useful within AAC, both at a general level for cuing (Jagaroo & Wilkinson, 2008) and also for specific issues such as facilitating single switch scanning as a selection technique (McCarthy et al., 2006).

In Dube et al. (2010), these within-stimulus prompts were effective in eliminating observing failures and increasing observing durations in four participants. In turn, there was also an immediate increase in accuracy scores for comparison selections to a range of 85% to 97% for three of these participants (Dube et al., Table 5, Participants DDA, WLN, STN). These results, along with those for the participant who received the pointing prompts, suggest that the earlier overselectivity was not due to some limit or deficiency in the ability to attend; these participants were clearly capable of performing the two-sample matching task with high accuracy. The problem was poorly organized and inadequate observing behavior -- they were not looking at all of the sample stimuli.

Results with one participant were different. The within-stimulus prompt intervention eliminated observing failures and increased observing durations to an average of 2.14 s per stimulus per trial, but accuracy improved very little, from 68% to 74%. The eye movement data showed that he was observing the stimuli, but the discrimination data (accuracy scores) indicated that he was not attending to them. Thus, interventions that improve observing behavior seem necessary but may not always be sufficient for the remediation of stimulus overselectivity.

One characteristic of this participant's observing topography was a large number of brief fixations; for example, the ratio of mean observing durations on trials with correct responses versus errors was greater for this participant than any other (Dube et al., Fig. 2, Participant

DTM). A final intervention with this participant addressed the issue of whether attending could be improved by imposing a contingency during within-stimulus prompting.

Training Broader Attention: Imposing Contingencies on Observing Behavior

A *contingency* refers to a relation between behavior and its consequences; in this case, the contingency was that the trial would not continue until the participant met a criterion for number and duration of fixations. Thus, this is an example of a contingency-based intervention approach. At the beginning of each trial, the touchscreen was de-activated. The experimenter watched the eye-tracking monitor showing the point of gaze and did not re-activate the touchscreen until there were a series of six fixations, three of each sample stimulus, each of at least 500 ms (estimated) duration. With this procedure observing durations increased to approximately 7 s per stimulus per trial and accuracy to 93%. The requirement for longer observing durations improved attending to the stimuli.

The researchers in the Dube et al. (2010) study implemented contingencies on observing behavior by experimenter interaction because the apparatus did not have the capability for gaze-contingent control of events. Gaze-contingent control is defined as the capacity to trigger changes in the stimulus display if and only if the observer's eye movements meet some specified criteria. Hardware/software eye tracking packages with this capability are becoming increasingly available, affordable, and easy to use. Gaze-contingent display technology was developed primarily to manipulate the amount of visual information displayed in relation to the observer's point of gaze (Duchowski, Cournia, & Murphy, 2004). However, the capacity to (a) define regions of interest within the stimulus displays on a computer screen, and (b) specify fixation requirements relative to those regions of interest would permit the development of interactive instructional programs with built-in observing requirements.

Remediation of Overselectivity: Differential Observing Responses

Despite the accelerating advances in eye tracking research technology, most AAC-related teaching is likely to occur in situations where eye tracking research technology is unavailable and therefore the learner's point of gaze is not precisely discernible. What can be done to promote adequate observing and reduce or avoid stimulus overselectivity when there is no eye tracking research apparatus available? One way is through implementation of differential observing responses. *Differential observing responses* refer to a class of procedures that can be used to verify observing and attending. Differential observing responses are defined by requirements that (a) promote observation of all of the relevant stimuli or stimulus features and (b) verify attending to these stimuli/features by some overt behavioral response.

Implementation of Differential Observing Responses to Reduce Overselectivity

Overselectivity may be greatly reduced when tasks are modified to incorporate differential observing responses (e.g., Dube, 2009; Dube & McIlvane, 1999). Although the result may be the same as that described above with the interventions that used eye tracking technology, the mechanism of action is slightly different. The prompting techniques used in the eye

tracking studies acted directly on the eye movement behavior itself, without changing the task requirements. In contrast, differential observing response procedures change the tasks in ways that impose additional behavioral requirements that encourage both observing and attending. Because of the additional behavioral requirements, differential observing response procedures are an example of a response-based intervention approach. This approach can be accomplished without access to the technologies required for eye-tracking recording, and thus it is more accessible from a clinical perspective.

For example, Gutowski, Geren, Stromer, and Mackay (1995) examined the effects of a differential observing response in two individuals with moderate intellectual disability who responded overselectively in a visual matching task. The sample stimuli were pictures of common objects and there were two samples on each trial. When the participants were required to name each sample aloud before making a comparison selection, accuracy scores improved. Note that the requirement to name the stimuli verifies discrimination among them and thus attending. In contrast, a requirement merely to point to each picture would be considered a non-differential observing response; because the overt behavioral response would be the same for each picture, it requires attending only to their locations and not to the relevant features that distinguish one picture from another.

As another easily-implemented example, consider the special-education student described earlier who identified words on the basis of the initial letter only, with resulting confusions between push and pull, and men and mug. One way to impose a differential observing response requirement would be to have the student spell the word aloud before reading it. When the student says, *m* and then *u* and then *g* there is evidence that he has observed each letter and attended sufficiently to make the discriminations among these specific letters.

It seems likely, however, that beginning communicators, and particularly those who may benefit from AAC, may not have skills such as spelling words or naming pictures that can be necessary for such differential observing responses. Indeed, the academic goal may be to teach the names that are related to pictures or symbols. Dube and McIlvane (1999) developed a nonverbal differential observing response procedure to address this problem. The procedure required only the ability to match identical visual stimuli and was based on multiple-cue training techniques that require simultaneous discrimination of two or more stimuli. Multiple-cue training was described in four earlier studies with children who showed overselective responding on initial assessments. Three of these studies used visual stimuli and the general format of the training was to select on every trial the compound stimulus A+B, and to reject the incorrect alternatives A+C, and A alone (Allen & Fuqua, 1985; Koegel & Schreibman, 1977; Schreibman et al., 1982). The fourth study used a matching task with multiple verbal cues; for example, *[touch the] big red pencil*, with incorrect alternatives that included a small red pencil, big blue pencil, and so forth (Burke & Cerniglia, 1990; similar training techniques are described in Rosenblatt, Bloom, & Koegel, 1995; and Schreibman, 1997). Results showed that overselectivity was reduced at least to some extent with trial-and-error training on multiple-cue problems.

The participants in Dube and McIlvane (1999) were three individuals with intellectual disability who had intermediate accuracy scores on the two-sample matching procedure

described above and in Figure 1, indicating stimulus overselectivity. The differential observing response procedure was presented during the sample observing period; participants were prompted to make matching responses that required observation and discrimination of both sample stimuli. For example, if the sample were AB, then the comparison stimuli were AB, AC, and DB. The participants could look back and forth between the sample and comparisons, and thus attending to both stimulus elements simultaneously was not required. When these differential observing responses were prompted, accuracy scores improved immediately. When the observing procedure was eliminated after 10 sessions, accuracy returned to intermediate levels. The results thus showed that stimulus overselectivity in a matching task could be greatly reduced, but that exposure to differential observing response requirements alone may be insufficient for lasting benefits.

A study by Walpole, Roscoe, and Dube (2007) extended the use of differential observing responses to educational stimuli. The participant was a young woman with autism spectrum disorder who had high matching-to-sample accuracy scores with printed words that had no letters in common (e.g., cat, lid, bug) but poor accuracy with words that had two letters in common (e.g., cat, can, car). In the differential observing intervention, she matched the distinguishing letters of the words (e.g., t, n, r) immediately prior to matching the whole words. Accuracy scores improved to high levels and accuracy remained high when the observing requirements were withdrawn.

In a variation of the identity-matching differential observing response technique, participants used a keyboard to match the individual letters of printed-word sample stimuli by typing them (Dube, 2009). For example, before matching the printed word, cup, the participant selected the letters c-u-p on the keyboard; these responses verified observing and attending to all of the letters in the word.

Another variation of this technique was used in Fisher, Kodak, and Moore (2007) to prompt observing of comparison stimuli while teaching relations of spoken words to pictures. Participants were children with autism (a) who had a history of slow or no progress in such tasks with traditional prompts such as the teacher pointing to the correct comparison stimulus, and (b) who had been observed to point to comparison stimuli without looking at them. During the identity-matching prompt condition, if the participant did not respond to a spoken-word sample by selecting the corresponding comparison picture, the experimenter repeated the sample stimulus while displaying a picture that was identical to the correct comparison as a prompt. In contrast to responses prompted by the teacher pointing, correct selections with the identity-matching prompt verified observing the comparison stimulus. Results showed improved accuracy scores when the identity-matching prompt was used.

Relation of Differential Observing Responses to Functional AAC Behaviors

When a clinician suspects that an individual using AAC is engaging in overselectivity, the research just reviewed offers potential solutions. For instance, some of the types of attention-grabbing motion cues discussed in Jagaroo and Wilkinson (2008) were demonstrated by Dube et al. (2010) to be effective in broadening fixation patterns and consequent behavioral responding in participants who initially demonstrated overselectivity.

Clinicians should therefore consider carefully how to incorporate those motion, size, and color-based cues as a means to attract attention to important information on an AAC display and to reduce the likelihood and consequences of overly narrow observing and attention patterns. The study by McCarthy and colleagues (2006) illustrates this point nicely. Specifically, they examined how well children without disabilities understood the function of the cue in serial single-switch scanning. Traditional scanning cues include a light that appears at the corner of each symbol, one by one until a selection is made, or a colored border enclosing the symbol. To use this cue functionally, an individual must understand that the symbol with the light or the enclosed border is the one currently “on offer.” McCarthy et al (2006) demonstrated that a cue that incorporated motion, specifically each symbol growing and then shrinking in size, improved children’s understanding of the function of the cue over the enclosed border cue.

Requiring differential observing responses to all parts of a stimulus holds particular potential for AAC interventions that support receptive skills of the individual. For instance, visual schedules that aid children in understanding and predicting the day’s events are composed of multiple components, each one typically representing one of the daily activities. If an individual appears not to be benefitting as expected from these visual schedules, instantiating differential observing responses at the outset of the day (and throughout, as needed) may promote better observation of each of the events being represented and thus, the likelihood of the individual understanding what is upcoming. Specifically, asking the child to point to each activity at the outset of the day and then on an ongoing basis throughout is an example of a differential observing response. Similarly, instruction on production of multi-symbol utterances that use some form of visual model may also benefit from implementation of differential observing responses to each of the elements. Once more, this might take the form of specifically asking a child to point to each element of the multi-symbol message as the adult model occurs.

Future Research Agenda

We have argued that at least some of the errors made by individuals who use AAC might be traced to presence of an overly narrow pattern of observing stimuli (stimulus overselectivity), including the types of stimuli that appear on AAC systems. If individuals who use AAC displays attend only to specific features of symbols on a display, they may fail to distinguish among symbols that share that particular feature. Hence, an individual who attends selectively to the stem on the top of a symbol may appear to confuse *APPLE* (a red, round fruit) with *PEAR* (an ovate, yellowish fruit). Or an individual who attends only to the first letters of a word (push) may similarly demonstrate errors when another word that shares those initial letters is introduced (pull). Indeed, in a demonstration of sight word vocabulary instruction in AAC, Wilkinson and Albert (2001) reported on just such a pattern in a learner who showed errorless learning until the words grannie and gramps were presented. Therefore, while not all errors made by individuals who use AAC may be traced to overselective attention, clinicians should be aware of the possibility and consider it as part of their troubleshooting strategy. This is particularly true given that such patterns are not confined to members of any one etiological category. Encouragingly, both the eye-tracking

work and the behavioral studies offer potential solutions when overselective responding is deemed a possibility.

As mentioned above, at present most AAC-related intervention is likely to occur in contexts that do not allow the teacher to track the student's point of gaze. With time, however, technologies often become more affordable, more widely available, and easier to use. At some point in the near future, many programs may have an eye tracking station integrated with a desktop computer. An important question follows: What types of software will be needed to maximize the potential for eye tracking to improve AAC instruction? Can continued research in stimulus overselectivity help to answer this question?

As one possibility, future research may be organized in terms of two broad categories: diagnostic for overselectivity and remedial for overselectivity. The goal of the former will be to develop assessment procedures that can quantify the adequacy of observing behavior to AAC displays or other educationally relevant visual stimuli. The use of eye tracking technology will allow determination of whether instances of overselectivity follow incomplete observing behavior, or whether observing is adequate and the issue is one of attending (as in the example of Participant DTM in Dube et al. 2010, discussed earlier). The distinction is important because the two types of problems may require different types of solutions. Another issue related to research on assessing overselectivity in AAC concerns the flexibility of observing behavior as the complexity of the display changes. An assessment is needed that will answer the diagnostic question of whether poor performance can be linked to failures to observe all relevant stimuli, or to failures to adjust observing durations as complexity increases (as in Dube et al., 2006). As a speculative example of how these questions might matter from an intervention standpoint, observing failures may be corrected by improving deficient visual search and scanning patterns to include fixations of all relevant stimuli. In contrast, attending failures may require changes in the durations of fixations to each specific symbol (Dube et al., 2006, 2010). Clearly, direct research is needed to support or refute such speculations.

Another research question is whether such an assessment will require standardized visual displays, or whether diagnostic algorithms can be developed that can relate the characteristics of observing behavior to any set of defined stimuli. If any set of stimuli can provide reliable diagnostic information, then it would be possible to incorporate the individual student's AAC displays directly into the assessment, thus supporting results that have direct relevance to intervention.

An additional assessment-related research question concerns whether overselectivity is more likely to occur with different types of AAC displays. For example, one may contrast grid displays, with rows and columns of symbols, with visual scene displays (VSDs) that use pictures related to a setting, situation, or activity. VSDs offer the advantage of a high level of contextual support, but this might come at the possible cost (for some learners) of increased visual complexity. Overselectivity may result from stimulus control restricted to one stimulus feature if that feature is shared by other stimuli. Thus, it is possible that the overall increased complexity of VSDs may increase the number of shared features and thus increase overselectivity relative to grid displays. It is also possible, however, that the

additional contextual information may promote stimulus control by stimuli as integrated compounds, rather than as collections of isolated features. Although no work has yet been conducted directly within AAC, Wilkinson, Light, and Drager (2012) have discussed some of the issues of “complexity” within grids versus VSDs, with regards to information from visual cognitive science and visual cognitive neuroscience (also see Wilkinson & Jagaroo, 2004).

To facilitate a discussion of future research in remediation of overselectivity, Table 1 summarizes the types of interventions discussed above and provides information on several descriptive variables. Response-based approaches such as the differential observing response have the advantages being immediately effective in many cases and requiring a low level of technical support. The disadvantages are that added task requirements mean additional time for instruction and a greater number of responses, for example, in discrete-trials instruction, 24 trials of matching to sample with differential observing responses requires 48 responses. In addition, some prior or additional training may be needed to establish the explicit observing responses such as learning to name the stimuli. One important research question concerns the best way to withdraw the instructional support provided by mandatory observing responses. Possibilities include omitting the requirement for an increasing percentage of trials; if so, the question becomes whether the omissions should occur early, late, or evenly distributed throughout an instructional session. Other possibilities are to develop methods to teach self-prompting strategies for observing, or to adapt strategies from Reichle and colleagues’ work (Reichle & McComas, 2004; Reichle et al., 2005; Reichle et al., 2008) in order to manipulate the strength of the reinforcer for self-prompted observing responses compared to externally-prompted responses.

Stimulus-based approaches (third column of Table 1) attempt to control observing behavior by manipulating stimulus materials. Examples include within-stimulus prompts such as sudden changes in stimulus salience, and extra-stimulus prompts such as verbal and gestural prompts. One strength of this approach is that it may be immediately effective; a related weakness is that the effectiveness may be due to novelty and thus short-lived. Our experience with stimulus-based interventions has been that procedures effective with some participants with intellectual disabilities might not be effective with others. One goal for future research is to develop rapid methods for using eye tracking research technology to determine the types of prompts that are most effective for individual learners. For instance: Is observing behavior more readily directed (and attending encouraged) by increasing the salience of the target stimulus, or decreasing the salience of surrounding stimuli? This question is relevant to AAC, in which a number of systems allow users to hide/mask or reveal symbols, with the goal of allowing for slow or controlled introduction of symbols over an acquisition period. Such a method seeks to highlight the target symbols by de-emphasizing the surround, however, its effectiveness relative to an alternative strategy that would specifically draw attention to the target warrants direct research. One might also ask: Does animation of a symbol as a prompt improve both observing and attending, or does it improve observing but decrease attending by competing with the relevant features of the stimulus? While Jagaroo and Wilkinson (2008) speculated about the role of motion cues for a number of functions in AAC, direct research on this topic within AAC remains sparse.

Contingency-based remediation approaches (fourth column of Table 1) may offer the greatest potential when combined with eye tracking research technology. In contingency-based remediation, the teacher manipulates the relation between one or more characteristics of observing behavior and the immediate consequence that follows that behavior. For example, a student may be required to observe a certain number of stimuli within a display before instruction proceeds. The advantages of this approach are that it does not introduce extraneous elements such as stimulus prompts or additional response requirements, and that there is no need to withdraw instructional support if behavior changes to meet or exceed the contingency. The increasing availability of gaze-contingent capabilities in eye tracking research technology offers a very attractive research opportunity. There is currently no mature technology for promoting compliance with observing contingencies, other than prompting. While conducting the research reported in Dube et al. (2010) the researchers merely waited until the participant met the contingency (sometimes for relatively long periods of time). Gaze-contingent displays would allow research using programmed response-shaping techniques (also known as differential reinforcement of successive approximation; e.g., Cooper, Heron, & Heward, 2007, Chapter 19). With such techniques, training begins with some behavior that is within the current repertoire, and then the criterion for reinforcement is gradually changed to elaborate the form of the response. Such changes may include gradually requiring longer and greater numbers of observations.

One final question seems applicable to all three categories of intervention: What is required to make durable changes in an individual's observing behavior? Recent research in the behavioral persistence of socially acceptable alternatives to problem behavior (e.g., Wacker et al., 2011) suggests that many months of training with very frequent reinforcement may be needed before new behavior becomes persistent enough to continue without contrived and often artificially high levels of reinforcement. If that is true for observing behavior as well, then generalized and enduring improvements may require frequent and continued practice over a relatively long course of instruction. It will be important to determine at a general level but also at the level of each individual how long it takes before changes instantiated by remediation can maintain in natural environments, which often include variable and perhaps unreliable reinforcement schedules. With smaller and lower-cost eye tracking research technologies such a research goal might be feasible.

General Summary

We have argued that overselective attention is quite likely to be a currently under-appreciated barrier to functional use of AAC by at least some individuals. We have sought to illustrate some of the ways that overselective attention may be relevant to AAC intervention practice and offered evidence-based methods for assessing overselective attention and potentially intervening when it occurs. A productive line of future research targeting issues specific to AAC is outlined, although it is by no means exhaustive. With further advances both in eye tracking research technologies and in the understanding of overselectivity within AAC, it may be possible to mitigate barriers introduced by overselective attention and promote more effective functional communication.

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Figure 1.

Delayed matching to sample with two-element sample stimuli; schematic illustrations not drawn to scale. A: Sample observation period. B: Participant touches the sample display area to terminate the observation period. C: Comparison stimuli are presented. The comparison stimulus in the upper right corner is the correct choice, identical to the right-side sample stimulus. The other two comparison stimuli are incorrect choices; they do not match either sample. The round sample stimulus (left side of sample) does not appear as a comparison on this trial.

Table 1

Categories and Characteristics of Intervention Techniques to Reduce Stimulus Overselectivity

	Response-Based	Stimulus-Based	Contingency-Based
Examples	Differential observing responses: naming, spelling, matching, etc.	Within- and extra- stimulus prompts	Minimum observing durations required to continue the task
Strength	May be immediately effective	May be immediately effective	Does not introduce extraneous elements
Weakness	Time-consuming, requires previously established behavior	Prompt effectiveness may be temporary	May be difficult to promote compliance with contingencies
Level of technological support	Low	Moderate (stimulus manipulation)	High (eye tracking)
Withdrawal strategy	Omit requirement	Prompt fading	None needed