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Selective attention to visual compound stimuli in squirrel monkeys (*Saimiri sciureus*)

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ABSTRACT

Five squirrel monkeys served under a simultaneous discrimination paradigm with visual compound stimuli that allowed measurement of excitatory and inhibitory control exerted by individual stimulus components (form and luminance/"color"), which could not be presented in isolation (i.e., form could not be presented without color). After performance exceeded a criterion of 75% correct during training, unreinforced test trials with stimuli comprising recombined training stimulus components were interspersed while the overall reinforcement rate remained constant for training and testing. The training–testing series was then repeated with reversed reinforcement contingencies. The findings were that color acquired greater excitatory control than form under the original condition, that no such difference was found for the reversal condition or for inhibitory control under either condition, and that overall inhibitory control was less pronounced than excitatory control. The remarkably accurate performance throughout suggested that a forced 4-s delay between the stimulus presentation and the opportunity to respond was effective in reducing "impulsive" responding, which has implications for suppressing impulsive responding in children with autism and with attention deficit disorder.

1. Introduction

A common procedure to assess stimulus control by the separate components of a compound stimulus is to first train a discrimination with the compound stimuli and then present the components in isolation. For example, Reynolds (1961; Experiment 1) trained two pigeons on a simple successive discrimination by reinforcing responses to a white triangle on a red background (S+) and extinguishing responses to a white circle on a green background (S−). During a test, he presented the forms without the background colors or the background colors without the forms. He found that one pigeon responded exclusively to the S+ form (triangle), the other to the S+ color (red). Virtually no responses occurred to either of the S− components. With this procedure, Reynolds provided an operational definition of "attention." However, while his procedure allows for an assessment of excitatory stimulus control by separate S+ components when above-zero response rates can be observed, it does not allow for an assessment of inhibitory control by the S− components. This is because zero responding to the S− components, due to a lack of excitatory control, is indistinguishable from zero responding due to effective inhibitory control by the S− components (i.e., a drop below zero responding is not detectable). For the assessment of inhibitory control, a so-called summation (combined-cue) test or retardation-of-acquisition (resistance-to-reinforcement) test must be applied (cf. Cole et al., 1997; for an early review, see Hearst et al., 1970). A further limitation of Reynolds' procedure is that only compound stimuli can be used of which the components are separable from each other (e.g., triangle can be presented without red background). However, discriminations reflecting real-life situations often do not involve compound stimuli with separable components. For example, if the S+ consisted of a spoken sentence phrased as a question and the S− consisted of another spoken sentence phrased as a statement, it would be impossible, for example, to separate prosody (inflection) from content, since a question cannot be presented void of content (Ploog et al., 2009). Based on these considerations, one purpose of the present study was to employ a test paradigm with primates — similar to the one used by Cole (1953), also with visual stimuli and monkeys — in an attempt to measure excitatory and inhibitory stimulus control by individual, inseparable stimulus components (e.g., measure control by "white" of a white circle compound stimulus) and to assess attention to these components as defined by Reynolds (1961).

A second purpose of the study was to assess squirrel monkeys' possible preference of color or form over the other. The literature on nonhuman and human primates' preference of color or form

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is somewhat inconsistent (possibly due to differences in procedure and population) even though most of the primate literature indicates a preference of color over form. For example, Révész (1925), using a discrimination paradigm with multiple simultaneous choices, reported preference of form over color in rhesus monkeys (*Macaca mulatta*). Harlow (1945b), criticizing Révész's work, tested performance of rhesus monkeys and Bonnet macaques (*Macaca radiata*) on a simultaneous discrimination task involving several sets of color stimuli, form stimuli, and combined color plus form stimuli. He found that performance was significantly lower with the form-only stimuli than with the stimuli involving color. Cole (1953), who contrasted Révész's and Harlow's procedures, also found preference of color over form in simultaneous discrimination learning in Pigtailed macaques (*Macaca nemestrina*) and rhesus monkeys. Casey (1979) reported that performance with form training was superior over color training in 1-year-old human infants whereas Kovattana and Kraemer (1974) found that there was no "cue dominance" of color, form, or size in typical, verbal autistic, or mentally retarded children, but that the nonverbal autistic children preferred color and size over form. Goldfarb and Balant-Campbell (1984) reported that left-brain damaged, aphasic adults preferred color over form more than right-brain damaged, nonaphasic adults, who in turn showed greater preference of color over form than control subjects.

Interest in relative preference of stimulus dimensions has a history in the study of individuals with autism because, as has been reported anecdotally and shown experimentally (e.g., Bickel et al., 1984; Colburn, 1984; Gersten, 1983; Hedbring and Newsom, 1985; Koegel and Wilhelm, 1973; Koegel et al., 1979; Matthews et al., 2001; Lovaas et al., 1971; Lovaas and Schreibman, 1971; Ploog and Kim, 2007; Schreibman et al., 1977, 1982, 1986), these individuals appear to be overly fixated on one aspect of a compound stimulus to the exclusion of other aspects. For example, in a landmark study based on Reynolds' (1961) paradigm, Lovaas et al. (1971) found that autistic children responded on average to one component only, mentally retarded children to two, and typical children to three components. There was no consistent preference for any modality, except that overall the autistic children responded little to the tactile cues and that there was no evidence of control by the temporal cue in any of the children. While selective attention is considered an adaptive behavior to filter relevant from irrelevant sensory information (Downing, 2000), Lovaas et al. (1971) interpreted their findings as indicating that autistic children exhibited overly selective attention (hence the term "stimulus overselectivity"). Ploog and Kim (2007) also found greater selectivity for one of two tactile components (form and texture) in autistic children than in typical children, but there was no consistent preference of one tactile cue over the other in either the autistic or the typical children. (Incidentally, Reynolds' pigeons also exhibited selective attention to color or form, but the preferred dimension was opposite for the two birds.)

The current study employed a simultaneous discrimination paradigm with visual compound stimuli (form: circle and rectangle; luminance: black and white — hence referred to as "color"). After being trained to a 75%-accuracy criterion with continuous and intermittent reinforcement (see below), the squirrel monkeys were tested with novel stimuli that consisted of recombined form and color cues, which allowed for the assessment of excitatory and inhibitory stimulus control by the individual components. An important feature of the current study was that during training the reinforcement rate was gradually reduced in order to avoid a generalization decrement between training and testing with respect to reinforcement rate. This very issue has been controversial from the beginning of most discrimination/generalization research. Both non-reinforcement of test trials (implemented in an attempt to *not* augment the associative or response strength) and reinforcement of test trials (implemented in an attempt to avoid the consequences of extinction) result in measurable changes of associative and response strength. Accordingly, Harlow and Poch (1945) criticized the reinforcement of test trials because "chance errors may be reinforced" (p. 353) and obscure the measurement of what was learned about the training stimuli. For this reason, Guttman and Kalish (1956) employed intermittent reinforcement during training before presenting generalization test trials. On one hand, the effect of intermittent reinforcement during training is that it increases resistance to extinction (e.g., Jenkins, 1962; Theios, 1962) so that more test trials can be presented before extinction affects responding to the test stimuli. On the other hand, intermittent reinforcement has the effect that the animal has had exposure to non-reinforced trials that will not be interpreted as "incorrect" (cf. Capaldi, 1966). In summary, intermittent reinforcement during training, while keeping reinforcement rates constant under testing, appears to be an appropriate way of minimizing the generalization decrement between training and testing while also minimizing the amount of learning that takes place during and as a result of testing.

Such a reduction of reinforcement rate during training in the current study led to a serendipitous finding that, if true, suggested that the introduction of intermittent reinforcement somehow facilitated discrimination learning. This, in turn, motivated the introduction of a reversal of the original discrimination (i.e., the original S+ became the S−, and vice versa). Ultimately, the reversal served three purposes: First, it would provide a within-subject replication — with swapped excitatory and inhibitory stimulus control — of preference for a given stimulus dimension. Second, the reversal would allow for the assessment of reversibility of excitatory and inhibitory stimulus control under reacquisition. Third, because during the original training there was some indication that the introduction of intermittent reinforcement facilitated discrimination learning, the reversal condition would provide an opportunity to compare the effects of continuous vs. intermittent reinforcement on the acquisition of a discrimination.

Another noteworthy feature of the present study was a 4-s delay between each stimulus presentation and the opportunity to respond, combined with the explicit omission of a correction procedure. A more common procedure, particularly in the nonhuman primate literature, consists of placing the stimuli below a panel (or behind a shutter) that can be removed at the onset of a trial as to allow the animal to respond immediately upon seeing the stimuli (e.g., Cole, 1953; Fragaszy, 1981; Harlow, 1945b; Peterson and Rumbaugh, 1963). It is known, however, that monkeys tend to respond immediately to stimuli that are closest to them (Révész, 1925, p. 300) perhaps accounting for sometimes lower accuracy in performance on relatively simple discrimination tasks than would generally be expected for primates. Thus, monkeys' choice behavior can be described as impulsive, in the sense that no response delay for stimulus evaluation and for decision-making is utilized. This pattern of responding is also characteristic of children with attention deficit disorder with or without hyperactivity (American Psychological Association, 2000, p. 92; see also Winstanley et al., 2006). For a review of common procedures to reduce impulsive responding see Baer and Nietzel (1991). One is to employ a forced delay between the stimulus presentation and the opportunity to respond just as was done in the present study.

In summary, this study's aims were (1) to test a paradigm to assess selective attention with respect to excitatory and inhibitory stimulus control, particularly when stimulus components cannot be presented in isolation, (2) to evaluate form vs. color preference in squirrel monkeys, and (3) based on a serendipitous finding as a result of a procedural consideration, to perform an initial exploration of the effects of intermittent reinforcement on discrimination learning.