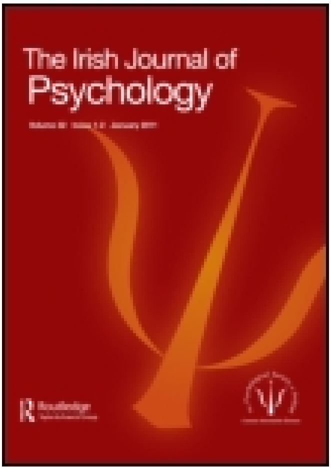


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# Conditional discrimination responding in non-humans

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# Conditional discrimination responding in non-humans

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Behaviour analysis employs the matching-to-sample procedure to study conditional discrimination responding in non-humans. A brief analysis of the studies to date is given with an emphasis on current research conducted in the Cork Laboratory employing naturalistic, or multi-modal, stimuli. The growing research area of stimulus equivalence is documented and the various studies that have failed to demonstrate derived responding in non-humans are outlined. Finally, methodologies for facilitating stimulus equivalence, or one of its properties, symmetry are described. The most efficient procedures are suggested as those that involve explicitly training symmetrical relations across multiple exemplars of naturalistic stimuli.

Within the experimental analysis of behaviour, studies concerned with supposedly cognitive processes in non-human animals have utilised the matching-to-sample procedure. Typically, in matching-to-sample trials subjects are first presented with a "sample" stimulus and then with two or more "comparison" stimuli. Choosing one of the comparisons in the presence of a given sample and not in the presence of another sample, is reinforced. This is termed a conditional discrimination, since the subjects response on a given trial is conditional upon the presence or absence of a sample stimulus.

Often conditional discrimination studies will employ trials where two of the stimuli, one of the samples and one of the comparisons, are physically identical. For example, in the presence of a green sample, selecting the green comparison is reinforced, (called "identity matching-to-sample", MTS), or alternately, selecting the red comparison may also be reinforced (called "oddity from sample", OFS; see Table 1). Having acquired the task, subjects are then tested for a generalisation of the MTS or OFS concept to novel, untrained, stimuli. A variety of stimuli and experimental arrangements have been used to examine both MTS and OFS performances with several species of animal, including monkeys (Oden, Thompson & Premack, 1988; Washburn, Hopkins & Rumbaugh, 1989), pigeons (Wright, Cook, Rivera, Sands & Delius, 1988; Wright & Delius,

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1994; Zentall, Edwards, Moore & Hogan, 1981), marine mammals (Herman, Hovancik, Gory & Bradshaw, 1989; Pack, Herman & Roitblat, 1991) and rats (D' Amato & Salmon, 1984; Iversen, 1993).

**Table 1.** A diagrammatic representation of matching-to-sample and oddity-from-sample trials.

| | SAMPLE | COMPARISONS | |
|---|---|---|---|
| MTS | Green | Green | Red |
| OFS | Green | Green | Red |

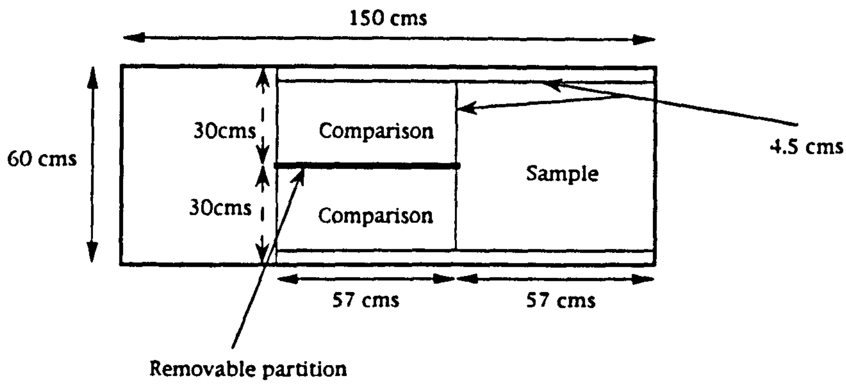
The number and variety of MTS and OFS studies is indicative of a healthy level of research concerned with the development of procedures to more readily facilitate the acquisition of generalized MTS or OFS responding in animals.

Perhaps a possible avenue of research open to the behaviour analyst interested in procedures to facilitate conditional discrimination responding in animals is to adapt the experimental context as naturalistically as possible. For example, Wright and Delius (1994) trained pigeons to dig in different coloured gravel for buried grain and found that the pigeons soon learned the task, with acquisition accelerating "100-fold compared to learning in traditional key-peck environments" (p. 108). These researchers, by taking a stimulus property of the natural world, coloured surfaces, and a response, digging in gravel, to which pigeons are naturally pre-disposed, and then superimposing the two, maintained a steady 90% acquisition rate by as early as the 27th trial (in contrast, some automated procedures result in acquisition in 1000 to 2500 trials; see Cumming & Berryman, 1965).

## Multi-modal identity matching-to-sample and oddity from-sample responding in rats

In the Cork Experimental Psychology Laboratory, we have recently initiated a series of studies employing rats in a modified Y-maze with stimuli that differ along a number of sensory dimensions (Dymond & Barnes, 1994). Specifically, we adapted the experimental device to suit a rat's natural locomotion between different tactile surfaces while foraging for food (see Figure 1). The multi-modal stimuli used were carpet, rubber (Set 1), wood, and foam (Set 2). Rats were trained to move from one surface (the sample) to the correct comparison (i.e., carpet to carpet [MTS], and carpet to rubber [OFS]).

**Figure 1.** The plan view of the experimental device.




*METHOD*

We employed a number of different procedures throughout the study with the objective of developing a reliable methodology for exploring conditional discrimination responding in rats. These procedures were as follows:

**(1) Double Baited Food Wells** Both food wells were baited with food, but a wire mesh inside the incorrect food well prevented access to it. This procedure allowed the animals to see and smell the food, whilst ensuring that their behaviour was under the discriminative control of the stimuli and not extra-experimental (e.g., smell) cues (see Thomas & Noble, 1988; Wright & Delius,1994).

**(2) Self-correction** On each trial, rats were allowed to move between comparison stimuli in order to find the correct comparison (i.e., the accessible food well). Thus, rats could self-correct their behaviour by moving from the incorrect comparison to the correct, and accessible, food well via the sample (see Nakagawa, 1992, p. 39).

**(3) Time-out and Inter-Trial Interval** After every trial, correct or not, rats were placed in a single home cage for an inter-trial interval (ITI) of 30s. No food or water was available in this cage. Following correct trials the experimenter used the ITI to re-arrange the stimuli for the next trial.

**Procedure**

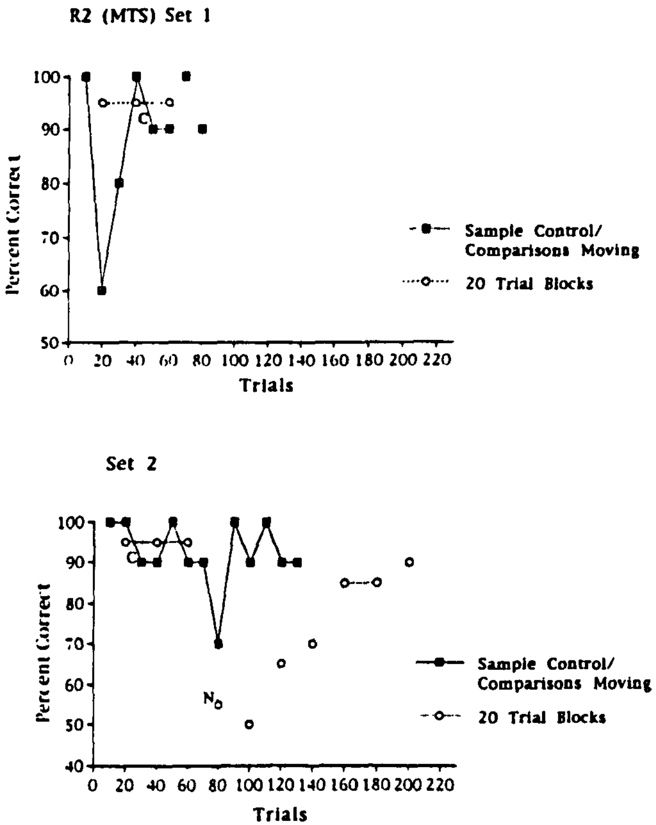
Acquisition was examined by first establishing sample control. That is, subjects were presented with the sample stimuli quasi-randomly and the comparison stimuli at invariant locations, which required them to discriminate the multi-modal properties of the sample before moving to a comparison. In effect, the rats could merely learn a spatial discrimination since the correct comparison, conditional upon the sample, was fixed on one side. Generally, all subjects had to produce at least 9 out of 10 correct responses (i.e., 90 percent accuracy) on each of two, 10 trial blocks before progressing to the next stage. In the next stage, the locations of the comparison stimuli were moved and each sample was presented for 10 trials with rats required to achieve 90 percent accuracy over two blocks with each sample. Finally, rats were exposed to blocks of 20 trials where the four possible trial types (2 sample and comparison dimensions x 2 left-right comparison configurations) were each presented five times until a criterion of 85-90% over three consecutive sessions was achieved.

*RESULTS*

The results for two rats are shown in Figures 2 and 3. With Set 1 stimuli, R2 required four sample control sessions before the comparisons were moved, and only three blocks of 20 trials to acquire MTS responding with two pairs of stimuli. R4 required two sample control sessions and a subsequent eight sessions with comparisons moving before seven exposures to the 20 trial blocks were necessary to acquire OFS responding (see Figures 2 and 3, upper panels).

During exposure to Set 2 stimuli, a more stringent criterion for defining an incorrect response was adopted. In Set 1, rats were allowed to approach the incorrect food well but not put their noses into the well. In Set 2 however, if a rat placed its four paws in the incorrect comparison the response was defined as incorrect and no food reinforcement was given. In effect, the animals were no longer allowed to approach the incorrect food well and then move to the correct companson. This modification greatly affected the rats' discriminations (Figures 2 and 3). R2, having acquired MTS responding across a second set of stimuli with the self-correction procedure, required seven further 20 Trial Blocks to reach the 85% criterion (see Figure 2, bottom panel). The "new criterion" was introduced earlier for R4 with a marked increase in the number of required trials to reach criterion (see Figure 2, bottom panel).

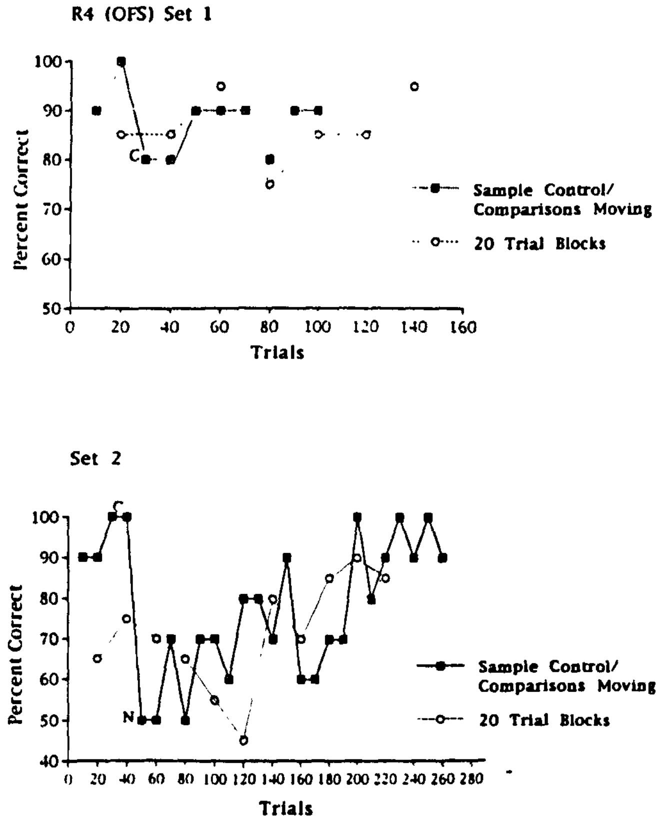
**Figure 2.** Acquisition of identity matching-to-sample responding across two sets of stimuli for Rat 2. The letter 'C' indicates the point at which the comparisons were moved. The letter 'N' indicates the point at which the new four-paws was introduced (see text for details).




## *DISCUSSION*

Overall, the apparatus and procedures of this study readily faciliated the acquisition of MTS and OFS responding in rats across two sets of multi-modal stimuli. The rate of learning observed in the study, an accuracy level of 90% by as early as the 120th trial (a mean of 135) during the 20 Trial Blocks, was extremely rapid compared to other studies that have employed standard operant chambers with either lever-pressing or keypecking as operants (e.g., Cumming & Berryman, 1965; Iversen, 1993; Zentall et al., 1981). In Iversen's study, for example, rats required 2500 or more trials to establish matching-to-sample (above 80% accuracy) using visual stimuli presented on nose keys.

**Figure 3.** Acquisition of oddity-from sample responding across two sets of stimuli for Rat 4. The letter 'C' indicates the point at which the comparisons were moved. The letter 'N' indicates the point at which the new four-paws was introduced (see text for details).




A number of factors may have been responsible for the effectiveness of the procedures. First, the stimuli used were multi-modal; they each differed on at least three sensory dimensions (i.e., visual, olfactory and tactile) and perhaps were more readily discriminated from each other than stimuli that differ only along one or two dimensions (e.g., hues). Second, the rats could earn reinforcers by moving from one multi-modal stimulus to another, where they could also obtain and eat the food reinforcement while actually standing on the comparison stimulus. Thus the correct comparison and the reinforcer were temporally and spatially contiguous (see also Wright et al., 1988). In contrast, in an operant chamber the comparison is usually not present when the reinforcer is consumed. Third, it is probable that the rat was not being controlled by the sample and comparison stimuli, but was merely discriminating the presence or absence of the wire mesh preventing access to the food reinforcement. Nevertheless, it is possible that this history of self-correction enhanced performance when the new four-paws criterion was introduced. Fourth, the sample and comparison stimuli were presented simultaneously, and thus the rats could actually stand on the sample and sniff or touch one of the comparison stimuli at the same time. Although successive presentation of samples and comparisons is generally considered to be more effective than is simultaneous presentation (Dube, Callahan & McIlvane, 1993), it remains to be seen whether the current simultaneous procedure is more effective for producing generalised matching and oddity responding in rats.



**Conditional discrimination and derived responding in non-humans**

The literature on conditional discriminations in non-humans includes an ever-increasing number of studies concerned with the behavioural phenomenon of stimulus equivalence. Stimulus equivalence involves training a subject in at least two conditional discriminations (e.g., given A1 pick B1, given B1 pick C1, given A2 pick B2, given B2 pick C2). For behaviour to be commonly defined as equivalent, subjects must demonstrate reflexivity, or generalized identity-matching (e.g., given A1 pick A1), symmetry, which requires that the trained relation be reversible or symmetric (e.g., given B1 pick A1), and transitivity (e.g., given A1, pick C1).

A wide variety of verbally-able human subjects have consistently shown stimulus equivalence (e.g., Barnes, 1994; Barnes, McCullagh, & Keenan, 1990; Devany, Hayes, & Nelson, 1986; Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan, 1982), while it has yet to be demonstrated unequivocally in nonverbally able humans and non-human populations (Dugdale & Lowe, 1990; Hayes, 1989). However, while research with non-humans is on-going, only one published study to date has shown clear evidence for stimulus equivalence (Schusterman & Kastak, 1993). Numerous researchers have tried and failed to show either symmetry (e.g., Dugdale & Lowe, 1990; Lipkens, Kop & Matthijs, 1988; Sidman et al., 1982), transitivity (Lipkens et al., 1988; Kuno, Kitadate & Iwamoto, 1994) or all of the tests for equivalence (Hayes, 1989; Yamamoto & Asano, 1995). However, the reporting of negative results has added substantially to both the debate of whether non-humans are capable of equivalence (Dube, McIlvane, Callahan & Stoddard, 1993; Zentall & Urcuioli, 1993) and to the knowledge base of procedures and methodologies that may facilitate derived (i.e., untrained) responding in animals. As Dube et al. (1993) point out:

> "Even if the ultimate goal of documenting equivalence is not achieved, however, there appear to advantages to a quantitative approach. One such benefit is that the systematic identification and evaluation of potential behavioral prerequisites is likely to contribute to a more complete specification of qualitative differences. Another potential benefit is the development of new methodologies" (p. 766).

In the Cork Laboratory, as a follow-on to the study on the acquisition of multi-modal MTS and OFS responding in rats, we have recently begun to research the usefulness of the methodology in demonstrating arbitrary conditional discriminations. We modified the following aspects of the procedure. To counteract the possibility that placing the rat on the sample allows for subtle and unintentional cueing on behalf of the experimenter, an entrance pipe was added to the sample end of the experimental device. This consists of a plastic pipe (54cms long and 12.5 cms in diameter), and at the beginning of each trial the rat is allowed to enter the pipe and make its way down to the sample, thereby preventing the experimenter from unintentionally positioning the rat in such a way as to make a particular left/right response more likely. Also, since there is some room for error in using the four paws criterion to define an incorrect response, the experimental device has recently had two one-way doors added to both comparisons in order to allow for more concise experimental control over the subject's choice.

Two rats were trained using a many-to-one format which is regarded as a more reliable procedure for demonstrating derived responding in animals (Zentall & Urcuioli, 1993). Specifically, four conditional discriminations were trained (i.e., B1->A1, B2->A2, C1->A1, C2->A2) with the objective of producing symmetry (i.e., A1->B1, A2->B2, A1->C1, A2->C2) and ultimately, equivalence (i.e., C1->A1, C2->A2). Rats were trained to a criterion of 90% accuracy across thirty two daily trials before eight nonreinforced symmetry probe trials were introduced. This procedure was continued until the subjects symmetrical responding on the eight trials had consistently emerged.

Results, though tentative and on-going, suggest that a history of non-reinforced symmetry probe trials interspersed with baseline training trials does not adversely effect rats accuracy levels. This finding has important implications for the stimulus equivalence in non-humans debate because it suggests that both a history of explicitly training bidirectional relations between stimuli (Schusterman & Kastak, 1993; Yamamoto & Asano, 1995) and repeatedly exposing subjects to probe trials interspersed with multiple exemplars (Schusterman & Kastak, 1993; Watt & Blackman, 1995) could offer researchers a reliable and efficient method for demonstrating derived responding in non-humans.

**Future Procedures**

A discussion of non-human conditional discrimination studies conducted to date is beyond the scope of the present paper (the reader is refereed to Dube et al. 1993, and Zentall & Urcuioli, 1993, for reviews of some equivalence procedures). However, some similarities can be discerned between the various procedures. I will briefly outline some of these procedures and make suggestions for further research.

**Explicit bidirectional training and multiple exemplars**

As mentioned above, a number of researchers have concluded that an animal's performance is greatly facilitated through explicit training wlth symmetry relations and a wide array of training and testing stimuli, or exemplars. Schusterman and Kastak (1993, p. 836) cited the experience with multiple exemplars as a critical factor of their sea lions' success on subsequent tests, a point also noted by Hayes (1989) and Yamamoto and Asano (1995, p. 17). Wright et al. (1988) also suggested that experience with a larger number of training trials will facilitate acquisition of a generalized MTS concept.

**Successive vs simultaneous**

Dymond and Barnes (1994) presented a unique method of simultaneous presentation of samples and comparisons. As outlined already, our procedure allowed the subject to discriminate the sample stimulus having made a choice (i.e., selfcorrecting an incorrect response), and ensured that the sample and comparison stimuli were present continuously while the rat consumed the food reinforcement on the correct comparison surface. In contrast, many automated procedures remove the stimuli once the operant response is made (e.g., in pigeon chambers by turning off the key-lights, or requiring differential responses to the sample before it is removed and the comparisons presented). Successive presentation, on the other hand, has its own advantages and it is up to the researcher to decide which procedure is best to facilitate responding in the subject species used (Dube et al., 1993).

**Naturalistic experimental contexts**

The on-going research in the Cork Laboratory has as its objective the demonstration of derived responding in rats using multi-modal stimuli. Procedures and methodologies of previous conditional discrimination studies have been employed and adapted to more readily facilitate the discriminative properties of the multi-modal stimuli in establishing derived relations in rats. I have already discussed the advantages of the experimental procedures, but the usefulness of the multi-modal stimuli cannot be understated. The Cork research allows for discrimination, or processing, of the stimuli along more than one modality. Such a protocol is an original addition to the non-human conditional discrimination literature, and lends the findings more ecologically-valid significance.

Overall, behaviour analysts are making great strides in the experimental analysis of behaviour (e.g., Barnes, 1994; Hayes, 1989; Schusterman & Kastak, 1993). However, much more still needs to be done before the debate about whether stimulus equivalence is a species-specific behavioural phenomenon is unequivocally answered. The advantages of research on derived responding with non-humans (i.e., controllable histories and environments) coupled with the continuing procedural insights of researchers should make it possible to refute conclusively that "being a sea lion makes one more capable of equivalence relations than does being a monkey, a baboon, or even a pigeon or a rat" (Sidman, 1994, p. 173). The future looks bright!



## *NOTE*

Data from this study was presented in the Behaviour Analysis in Ireland group symposium at the annual conference of The Psychological Society of Ireland, Killarney, November, 1994. I thank the management and technicians of the Biological Services Unit, U. C. C. for their support of the project and for expert maintenance of the animals. Also, Pat O' Donovan, Roger Dymond, and Pip for assisting in the construction of the box. Dermot Barnes assisted in the analysis of the many-to-one relations.

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