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The effects of changeover delays on local choice

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ABSTRACT

In concurrent schedules with a changeover delay (COD), choice often strongly favours the just-reinforced alternative immediately after a reinforcer delivery. These 'preference pulses' may be caused by a change in reinforcer availability created by the COD, and/or because the COD decreases the overall probability of switching. We investigated which explanation better accounts for preference pulses by arranging concurrent schedules that allowed us to separate the COD's effects on reinforcer availability from its effects on the probability of switching. When the reinforcer ratio was 1:1, pulses were inconsistently accompanied by changes in reinforcer availability, but consistently accompanied by longer visits. These pulses appeared to be related only to the decreased probability of switching caused by the COD, providing the first evidence of pulses after reinforcers caused by the probability of switching alone. When the reinforcer ratio was 1:5 or 5:1; preference pulses were accompanied by changes in reinforcer availability and by longer visits. These pulses appeared to be related to the COD's effects on reinforcer availability, although a small portion appeared to be related to low probability of switching. These findings suggest that the COD affects preference pulses by both decreasing the probability of switching and creating a change in reinforcer availability.

1. Introduction

A longstanding question in the experimental analysis of behaviour concerns the processes that underlie choice behaviour. Choice behaviour is typically examined by arranging a concurrent schedule, in which reinforcers are available on two or more response alternatives (Ferster and Skinner, 1957). The overall distribution of responses between alternatives (the *response ratio*) provides a measure of overall choice. Traditionally, the overall distribution of reinforcers between alternatives (the *reinforcer ratio*) has been thought to determine response ratios (Baum, 1974; Herrnstein, 1961, 1970). However, the extent to which response ratios equal (i.e., 'match') reinforcer ratios depends on the arrangement of a changeover delay (COD; Herrnstein, 1961) – a brief period of time during which no reinforcers can be obtained, beginning from the first response on one alternative following responding on the other (Dreyfus et al., 1993; Menlove, 1975; Pliskoff et al., 1978; Shahan and Lattal, 1998; Silberberg and Fantino, 1970). The COD has no effect on the overall reinforcer ratio, and hence should not affect choice if choice is controlled solely by events on a global scale such as the overall reinforcer ratio. However, the COD does alter the likely availability of reinforcers across *time*. This change in local reinforcer contingencies appears to have strong effects on concurrent-choice performance, suggesting that overall choice also depends on *local* reinforcer probabilities.

1.1. Local reinforcer contingencies after switches

The main effect of the COD on local reinforcer contingencies is to alter local reinforcer probabilities after switches. In concurrent schedules with a COD, every switch is followed by a period of non-reinforcement, and any reinforcers arranged on the switched-to alternative are only delivered after the COD ends. This results in a large proportion of reinforcers being delivered immediately after the COD, relative to at other times (Dreyfus et al., 1982; Menlove, 1975). This delay to reinforcer deliveries after switches has a powerful effect on behaviour. For example, Shull et al., 1981 varied the delay between switch responses and reinforcer deliveries that were contingent on switching, and found that the rate of switching increased as the delay decreased, even if frequent switching decreased the overall reinforcer rate. Thus, the delay to reinforcement after switches appeared to control the rate of switching more strongly than the overall reinforcer rate (see also MacDonall, 2015; Shahan and Lattal, 1998, 2000).

The COD also alters patterns of responding in the seconds after a switch. Response rates during the COD tend to be higher than response rates at other times (Dreyfus et al., 1993; Menlove, 1975; Pliskoff, 1971; Shahan and Lattal, 1998; Silberberg and Fantino, 1970), probably

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because a larger proportion of reinforcers is obtained immediately after the COD than at other times (Dreyfus et al., 1982; Menlove, 1975; Pliskoff et al., 1978). Additionally, response rates during the COD increase gradually, typically reaching a maximum at the end of the COD (Pliskoff et al., 1978; Shahan and Lattal, 2000). This response-rate pattern is similar to that obtained in fixed-interval schedules, in which response-contingent reinforcers are delivered at regular intervals and responding during inter-reinforcer intervals is controlled by the temporal proximity to the next reinforcer (i.e., an FI scallop; Ferster and Skinner, 1957; Skinner, 1938). Hence, the pattern of responding during the COD appears directly related to the heightened probability of reinforcer deliveries immediately after the COD. These changes in response rates during the COD result in systematic differences between response ratios calculated from responses made during and outside of the COD; response ratios are less extreme than reinforcer ratios during the COD, whereas the reverse is true outside of the COD (Shahan and Lattal, 1998; Silberberg and Fantino, 1970; Temple et al., 1995). This in turn alters overall response ratios (e.g., Catania, 1963; Menlove, 1975; Pliskoff et al., 1978; Shahan and Lattal, 1998; Silberberg and Fantino, 1970; Temple et al., 1995). These local-level effects of the COD on responding appear to be partly responsible for the difference between overall choice in concurrent schedules with and without a COD (e.g., Dreyfus et al., 1982; Pliskoff et al., 1978; Shahan and Lattal, 1998; Silberberg and Fantino, 1970).

1.2. Local reinforcer contingencies after reinforcer deliveries

In addition to creating a change in reinforcer availability after switches, the COD alters local reinforcer contingencies after *reinforcer deliveries* (Cowie et al., 2011; see also Boutros et al., 2009, 2011; Cowie and Davison, 2016; Davison et al., 2013). After a reinforcer delivery, switching to the other alternative (the *not-just-productive* alternative) initiates the COD, and hence reinforcers are not available until the COD ends. In contrast, no COD operates if subjects stay on the just-productive alternative, and hence, if arranged, reinforcers may continue to be obtained from the just-productive alternative. That is, when a COD is arranged, reinforcer deliveries are followed by a period of *exclusive* reinforcement on the just-productive alternative; any reinforcers obtained in the first few seconds after a reinforcer delivery can only be obtained from the just-productive alternative.

Thus, in concurrent schedules with a COD, reinforcer deliveries may be followed by local changes in responding that depend on changes in reinforcer availability, just as responding after switches depends on local reinforcer contingencies after switches (see Section 1.1). Indeed, analyses of response ratios over time since a reinforcer delivery (*local choice;* Cowie and Davison, 2016) have shown that in concurrent schedules with a COD, reinforcer deliveries are often followed by a brief period of heightened preference toward the just-productive alternative. Thereafter, choice shifts toward and stabilizes at the level of the overall reinforcer ratio (e.g., Davison and Baum, 2002; Krägeloh and Davison, 2003; Landon et al., 2002, 2003; see also Cowie and Davison, 2016). This transient change in choice is called a *preference pulse* (Davison and Baum, 2002). In concurrent schedules without a COD, such pulses are absent, or are less extreme and more transient than pulses in schedules with a COD (Baum and Davison, 2004; Davison and Baum, 2000; Krägeloh and Davison, 2003; see also Cowie et al., 2011). The absence of preference pulses in concurrent schedules without a COD is consistent with the view that preference pulses are caused by changes in reinforcer availability; when no COD operates, no change in reinforcer availability occurs after reinforcer deliveries.

Findings showing that responding is controlled by time-based changes in reinforcer availability after switches in concurrent schedules with a COD (see Section 1.1), strongly suggest that the COD-produced change in reinforcer availability after reinforcer deliveries is responsible for preference pulses. In fact, such control by local reinforcer contingencies may be stronger after reinforcer deliveries than after switches, because reinforcer deliveries are probably more salient events than switch responses (e.g., Fox and Kyonka, 2015, 2016; see also Williams, 1991; Real, 1983). Recent research demonstrating that local choice follows changes in the local reinforcer ratio over time since a reinforcer delivery provides further support for the view that preference pulses are caused by changes in the local reinforcer ratio (e.g., Cowie et al., 2011, 2013; see Cowie and Davison, 2016 for a review). However, although numerous studies have examined how local reinforcer contingencies after switches affect responding in concurrent schedules with a COD, less is known about the effects of the COD on responding after reinforcer deliveries. Furthermore, studies demonstrating control by local reinforcer ratios after reinforcer deliveries have not explicitly investigated the effects of the *COD* on the local reinforcer ratio and local choice. Therefore, whether local reinforcer contingencies control responding after reinforcer deliveries in concurrent schedules with a COD remains to be seen.

1.3. Indirect effects of the changeover delay on preference pulses

Although the change in local reinforcer availability after reinforcer deliveries appears to be responsible for changes in local choice (preference pulses) after reinforcers in concurrent schedules with a COD, some evidence suggests that preference pulses may instead be attributed to the reduction in the probability of switching caused by the COD (McLean et al., 2014). That is, preference pulses are an *artefact* of the change in local reinforcer contingencies after switches caused by the COD: The COD creates a period of nonreinforcement after switches, hence decreasing the overall probability of switching (see Section 1.1), and this in turn results in preference pulses after reinforcers.

McLean et al. (2014) described how the decrease in the probability of switching caused by the COD may cause preference pulses. Concurrent-choice performance can be separated into visits to each alternative, and the length or duration of visits depends on relative reinforcer rates and on manipulations that affect the probability of switching (Shull and Grimes, 2003; Smith et al., 2014). At any time, subjects choose between staying and continuing a visit, or switching and beginning a new visit (MacDonall, 1999, 2009, 2015; McLean et al., 2014). Reinforcer deliveries are delivered during visits, hence, after reinforcer deliveries, subjects choose between continuing the current visit or beginning a new visit – a choice that depends on the overall probabilities of staying and switching, regardless of local reinforcer ratios. If the probability of staying is high and the probability of switching is low, as is the case when a COD operates (Herrnstein, 1961; MacDonall, 2015; Menlove, 1975; Shahan and Lattal, 1998; Shull and Pliskoff, 1967), then subjects will prefer the just-productive alternative after reinforcer deliveries, resulting in preference pulses.

Preference pulses may therefore be more extreme and longer lasting in concurrent schedules with a COD than in schedules without a COD because the COD reduces the probability of switching, and not because the COD creates a change in the local reinforcer ratio. Indeed, some research suggests that the rate of switching plays a large role in determining levels of preference, independent of relative reinforcer rates (e.g., Belke, 1992; Gibbon, 1995; Mark and Gallistel, 1994; McDevitt and Bell, 2008, 2013; Williams and Bell, 1996). For example, McDevitt and Bell (2013) arranged a multiple schedule in which each component consisted of a concurrent variable-interval (VI) 40-s VI 80-s schedule with a COD. In one component, the COD was 1 s, whereas in the other component, it was 10 s. After training, McDevitt and Bell measured preference in unreinforced probe trials, in which one alternative from the Short-COD component and one alternative from the Long-COD component were presented concurrently. Generally, subjects preferred the alternative associated with the long COD in probe trials, even when both alternatives were associated with the same reinforcer rates (e.g., both VI 40 s). This preference appeared to be related to the rate of switching in each component. The rate of switching in the Long-COD component was lower than in the Short-COD component, resulting in