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Determinants of stereotypic and variable eye-movement patterning:
Experimental analysis and clinical implications

DOCTORAL THESIS

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Stefanos Diakos

Abstract

Differential positive reinforcement has been observed to alter eye movements, but the effects of punishment on eye movement-patterning have yet to be investigated. Moreover, mainstream theoretical formulations of punishment omit essential effects that may affect behaviors that are temporally distal from the punitive event. One of them is the power of punishment to establish the negative reinforcing potency of stimuli mechanically produced by the punished responses, from which relief may often be obtained in the emission and repetition of action patterns that have not been punished. Stereotypic replication of 'safe' action patterns becomes problematic when it is evoked in contexts that demand greater variability levels. In a series of two experiments, the power of punishment to evoke generalized stereotypic visual-motor fixation patterning was examined using eye tracking technology, when such patterning itself was neither punished nor reinforced by experimenter-controlled events. In Experiment 1, in a two-link chain, neurotypical adults initially fixated serially on each of four black dots in any order with no scheduled effect; then they searched for a small white dot that appeared momentarily on one of the four black dots. Correct detection and guesses of the location of the white dot were reinforced with points; errors received no consequences save the initiation of a new trial. In the second phase, second-link detection errors were either punished (experimental group) or not punished (control group) with point loss. While fixation patterning itself was never punished, second-link punishment evoked increased pattern repetition in the first link; baseline variability levels partially recovered with the termination of punishment in Phase 3. This generalized effect of punishment was not observed in Experiment 2, where in the first link, subjects had to produce eye fixation patterns that differed from the last-emitted pattern. Under these conditions, instead of stereotypy, punishment evoked even more variable visual-motor fixation patterning. A context of punishment tends to evoke generalized repetition of recently-emitted, unpunished fixation patterns in humans, even when such topographic stereotypy or variability is not itself functional; this effect may be blocked or reversed with the differential reinforcement of variability. These findings, along with their theoretical formulation of punishment effects, could prove to be helpful in clinical cases where atypical eye-movement patterning is observed, such as in autism spectrum disorder, attention-deficit/hyperactivity disorder and Alzheimer’s disease.

Keywords: eye tracking, warning signal, automatic punishment, automatic negative reinforcement, side effects of punishment, autism spectrum disorder, attention deficit hyperactivity disorder

Παράγοντες που καθορίζουν στερεοτυπικά και μεταβλητά μοτίβα κίνησης των ματιών: Πειραματική ανάλυση και κλινική σημασία

Περίληψη

Ενώ η διαφορική θετική ενίσχυση έχει παρατηρηθεί πως μπορεί να αλλάζει τις κινήσεις των ματιών, οι επιδράσεις της τιμωρίας στα μοτίβα βλεμματικής συμπεριφοράς δεν έχουν ακόμα επαρκώς μελετηθεί. Επιπλέον, οι επικρατούσες θεωρήσεις της τιμωρίας παραβλέπουν ουσιώδεις επιδράσεις της, οι οποίες μπορεί να είναι χρονικά απομακρυσμένες από το τιμωρητικό γεγονός. Μία από αυτές είναι η θεμελίωση της αρνητικά ενισχυτικής δύναμης των ερεθισμάτων που παράγονται από τις τιμωρημένες δράσεις, από τις όποιες μπορεί να «αποκτηθεί» ανακούφιση και ασφάλεια μετά από εκδήλωση και επανάληψη μοτίβων συμπεριφοράς που δεν έχουν τιμωρηθεί. Η στερεοτυπική επανάληψη «ασφαλών» μοτίβων δράσης καθίσταται προβληματική όταν εκδηλώνεται σε πλαίσια, τα οποία απαιτούν συμπεριφορές με μεγαλύτερη μεταβλητότητα. Σε μια σειρά δύο πειραμάτων, μελετήθηκε με τη χρήση τεχνολογίας καταγραφής των οφθαλμοκινήσεων, η δυνατότητα της τιμωρίας να προξενεί γενικευμένη στερεοτυπική παραγωγή οπτικοκινητικών μοτίβων εστίασης, όταν η παραγωγή των μοτίβων αυτών δεν τιμωρούταν ούτε ενισχυόταν μέσω κάποιου πειραματικά ελεγχόμενου τρόπου. Στο πρώτο πείραμα, σε μια συντελεστική αλυσίδα δύο κρίκων, ενήλικες εστίαζαν αρχικά το βλέμμα τους σειριακά σε τέσσερεις μαύρες βούλες με οποιαδήποτε σειρά επιθυμούσαν χωρίς κάποια προγραμματισμένη συνέπεια· στη συνέχεια, έψαχναν μια μικρή άσπρη βούλα που εμφανιζόταν στιγμιαία εντός μιας από τις τέσσερεις μαύρες βούλες. Η σωστή ανίχνευση ή το μάντεμα της τοποθεσίας της άσπρης βούλας ενισχυόταν με πόντους· τα λάθη στην ανίχνευση δεν παρήγαγαν κάποια συνέπεια, εκτός της εκκίνησης της επόμενης δοκιμασίας. Στη δεύτερη φάση, τα λάθη στην ανίχνευση είτε τιμωρούνταν είτε όχι με αφαίρεση πόντων. Ενώ η παραγωγή οπτικοκινητικών μοτίβων εστίασης δεν τιμωρούνταν καθόλη τη διάρκεια του πειράματος, η τιμωρία στον δεύτερο κρίκο της αλυσίδας προξένησε επαναλαμβανόμενη παραγωγή μοτίβων στον πρώτο κρίκο· τα επίπεδα μεταβλητότητας επανήλθαν στα αρχικά επίπεδα, όταν αφαιρέθηκε η τιμωρία από το περιβάλλον στην τρίτη φάση. Αυτή η γενικευμένη επίδραση της τιμωρίας δεν παρατηρήθηκε στο δεύτερο πείραμα, όπου στον πρώτο κρίκο της αλυσίδας οι συμμετέχοντες έπρεπε να παράγουν μοτίβα που διέφεραν από το αμέσως προηγούμενο μοτίβο. Κάτω από αυτές τις συνθήκες, αντί για στερεοτυπική επανάληψη οπτικοκινητικών μοτίβων εστίασης, η τιμωρία προξένησε την παραγωγή πιο μεταβλητών μοτίβων. Φαίνεται πως ένα τιμωρητικό πλαίσιο τείνει να προξενεί γενικευμένη επανάληψη μοτίβων, τα οποία έχουν εκδηλωθεί πρόσφατα και δεν έχουν τιμωρηθεί, ακόμα και όταν αυτή η στερεοτυπία/μεταβλητότητα δεν είναι με κάποιο τρόπο λειτουργική, ενώ η επίδραση αυτή μπορεί να εμποδιστεί ή ακόμα και να ανατραπεί με τη διαφορική ενίσχυση μεταβλητών μοτίβων στον πρώτο κρίκο της αλυσίδας. Αυτά τα ευρήματα, μαζί με τη θεωρητική ανάλυση των επιδράσεων της τιμωρίας, μπορεί να καταστούν βοηθητικά σε κλινικές περιπτώσεις όπου παρατηρούνται μη-τυπικά επίπεδα οπτικοκινητικών μοτίβων, όπως στη διαταραχή αυτιστικού φάσματος, στη διαταραχή ελλειμματικής προσοχής και υπερκινητικότητας και στη νόσο Alzheimer.

Λέξεις-κλειδιά: τιμωρία, αρνητική ενίσχυση, προειδοποιητικά σήματα, σήματα ασφάλειας, επιδράσεις της τιμωρίας, διαταραχή αυτιστικού φάσματος, διαταραχή ελλειμματικής προσοχής και υπερκινητικότητας

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Introduction

Eye movement and adaptive behaviors

Natural selection has shaped and still shapes the human visual system in a way that increases the chances of humankind's survival. The interplay between the factors inside and outside the organism provides the ability to humans (as well as non-humans) to perform highly accurate visually-based behaviors that may facilitate their lives in the short term and the long term for their species' perpetuation. For example, when dehydrated, seeing a bottle of water may evoke a series of actions that will effectively produce water. Similarly, when a potential threat is getting closer, its image may evoke behaviors that have terminated similar threats in the past. The evolutionary value of visually-based behaviors is evident when people are born with or acquire visual deficits. Apart from the social stigma surrounding severe vision problems, especially blindness, these individuals face significant difficulties adapting to new environments without verbal instructions or other supportive stimulation.

From a behavioral-analytic point of view, eye movements constitute behaviors that may be maintained or differentiated based on their consequences (operant behavior; e.g., Berger, 1968; Madelain et al., 2011; Schroeder & Holland, 1968; Steingrimsdottir & Arntzen, 2016). Although neuroanatomical factors determine the perceived sensory features of the visual field (e.g., color, contrast), certain aspects of eye movements, such as the duration, the path, or the variability of fixations are at least partially controlled by their differential reinforcement history (e.g., Hall et al., 2009; Madelain et al., 2007). In contrast, cognitive models are based on hypothetical constructs such as “Schema control” and “Gaze system” (Land, 2009) in order to explain eye movement patterns. However, their most important weakness is that they ignore or at least underestimate the organism-environment dynamic contingency interaction and inevitably assign a more static role to visual-guided behaviors.

Furthermore, behavior-analytic accounts of eye movements do not suggest multiple and domain-specific mechanisms/principles/models for the shaping, maintenance and extinction of visually-guided behaviors. Although anatomical and functional boundaries undoubtedly exist among sensory systems, eye movements share a common potentiality with other motor responses (hand, tongue movements and others): they can operate upon the environment and their consequences may change their frequency of occurrence in the future (e.g., Holland, 1957; Skinner, 1938). For example, a child is told by her father that there is a sweet in a bowl somewhere in the kitchen. Following her father's directions, the child enters the kitchen and sees a bowl on the kitchen counter; she approaches the bowl and then grasps the sweet that it contains and eats it. Although this six-step description might satisfy the needs of the layperson, for an operant chain analysis it is inadequate because it ignores a very important link of the behavioral cascade: the searching for the bowl elsewhere. In particular, when the child enters the kitchen, she does not directly observe the bowl. Instead, she looks around, for instance, at the table. If no bowl is on the table, continuing to look at it serves no function, and the empty table evokes (as differential context of reinforcement or S^D) the continuation of searching. Then she looks at the kitchen counter, and again, if no bowl is on it, given her history of reinforcement, she will probably keep searching. However, if the bowl is on the counter, the image of the bowl will function as an S^Δ (differential context of extinction) for the continuation of searching and as an S^D for approaching the bowl.

The analysis above increases the analytic power of the layperson's six-step formulation because it explicitly stresses the dynamic role of eye movements. The child's eyes did not turn to the bowl automatically after entering the kitchen. Traditionally called observing responses (e.g., Dinsmoor, 1985; Kelleher et al., 1962; Wyckoff, 1952; see Hansen & Arntzen, 2015), these behaviors are controlled by the consequences that they have produced and by the contexts in which they are differentially effective. Specifically, humans' various saccadic eye movements (as well as microsaccadic; see Paeye & Madelain, 2011) are emitted depending on the stimuli they produce (i.e., an image of an empty table versus bowl on the counter), evoking the continuation of searching or its termination.

Therefore, the above eye motor searching patterns depend on the interaction between the subject and the environment and are not pre-determined prior to the emission of the relative actions. Of course, this does not mean that possible eye movement patterns are randomly produced. Some of them were more effective than others in the past because they produced (more frequently) specific conditional or unconditional reinforcers, whereas other patterns did not. Thus, the effective patterns will tend to occur in similar circumstances, whereas ineffective actions will not. For example, suppose that under similar conditions in the past, scanning the kitchen counter led to the terminal reinforcer more frequently than scanning the shelves did. In that case, the child will tend to look first at the counter and only then (or not at all) at the shelves. After a possible contingency switch in which the searching of the shelves is more frequently reinforced than searching at the counter, her eye movement behavior will be reversed (e.g., Berger, 1968; Madelain et al., 2011). Past history of differential reinforcement and non-reinforcement determines which patterns will be emitted in particular contexts and which patterns will not.

Levels of relative stereotypy or variability across reinforced chains of eye movements are likely to constitute a vital dimension of the adaptation of visual-motor activity to current contingencies of reinforcement, because different types of activity require different levels of behavioral stereotypy/variability. For example, under differential reinforcement of stereotypy in eye movement-patterning, the stimuli produced by each successive link of a chain or pattern of eye movements would tend to evoke an action corresponding topographically to that evoked on previous reinforced trials or occasions. In contrast, under differential reinforcement of *variable* patterning, the stimuli produced in a given link would tend to evoke actions that *differ* topographically from reinforced actions that preceded it.

A simple example of the former case can be found in the children's game "hide and seek." When the seeker locates a concealed player, he or she usually does not look in the same spot for the next hidden player, but rather searches in a different location. In behavioral terms, the former location functions as an S^{Δ} for re-searching in the same spot and an S^{D} for searching in different spots. Therefore, the searching pattern produced is not a result of a mental strategy or of cognitive mapping but of differential reinforcement of topographically variable searching and extinction (and probably punishment) of repetition of effective patterns. Of course, the seeker may be aware of effective search patterns and be able to describe them in detail, but this does not mean that his/her actions depend on unseen "cognitive processes" inside his mind; he/she has formulated an accurate rule of relation between behavior and environment, which he/she might reproduce on similar occasions, evoking effective actions in himself/herself or others.

This process of operant conditioning may of course be reversed. Under differential reinforcement of *stereotypy* in eye movement-patterning, the stimuli produced by each link of an eye movement pattern would tend to evoke an action topographically *similar* to that evoked on previous occasions. For example, waiting at a bus stop produces the reinforcing image of the bus only after the appropriate eye movement and fixation. Ocular movements in the opposite direction or irrelevant regions are less frequently emitted because they do not produce the reinforcing image of the bus, which might then pass unobserved. Therefore, stereotypic patterns usually prevail in the above case and in many routine situations requiring sustained attention. Of course, this is not an inviolable rule but in general when the conditional or unconditional reinforcer is produced exclusively by a certain action with parallel extinction of other acts, it is anticipated that levels of stereotypy will be raised (e.g., Antonitis, 1951; Page & Neuringer, 1985; see Balsam et al., 1998, and Lee, 2007 for reviews).

Although to date only two studies have attempted to control eye movement diversity levels under experimentally controlled conditions (Madelain et al, 2007; Paeye & Madelain, 2011), it appears that ocular pattern variability can be differentiated by its consequences when the schedule of reinforcement is arranged appropriately. For example, Paeye and Madelain (2011) arranged an experimental context such that the production of conditional acoustic reinforcers depended upon the emission of visual saccades that differed bi-directionally in amplitude (i.e., distance traveled by the eyes between two fixation points) from the median value of previously-emitted saccades. They observed then that the dispersion of amplitudes became more variable when only those saccades that differed in amplitude from recently-reinforced saccades were reinforced. This saccadic endpoint variability was decreased to its baseline level when it was no longer differentially reinforced.

The effects of selective *punishment* of eye movement patterns that repeat or differ topographically from previously-emitted patterns have yet to be observed under controlled conditions. However, studies concerning other forms of visually-guided motor behavior have indicated that the selective punishment of repetition of motor patterns increases topographical variability when the emission of more varied patterns terminates conditional or unconditional negative reinforcing stimuli (i.e., aversive events).

For example, Fonseca Júnior and Hunziker (2017) reinforced the completion of a series of three lever presses distributed over two levers (in rats) on the condition that the current series differed from the previously reinforced sequences. A warning *signal* (see below) for programmed electric shock could be terminated by the emission of a series of lever presses that differed from the recently-reinforced series; any behavior incompatible with auto-differentiation in serial lever pressing was punished. This combination of punishment of failure to vary and negative reinforcement of auto-differentiation produced and maintained higher levels of topographical variability in the series of lever presses.

Similar behavioral patterns of problematic levels of visual-guided variability may be observed in some so-called “psychological disorders”. For instance, in Attention-Deficit/Hyperactivity Disorder (ADHD), the criteria concerning the domain of *Inattention* include careless mistakes and difficulties in sustaining attention during daily activities, deficits in organizing tasks that require sequential order, and aversion to tasks that require mental effort (DSM-5-TR; APA 2022). From a behavioral-analytic perspective, attention deficits point to the ineffectiveness of certain environmental cues to evoke adaptive behavior. This weakness is evident in sequential tasks because, in these activities, the stimuli that function as S^D and S^Δ are not static; rather they acquire and lose reinforcing potency depending on multiple other behavioral elements of the context (which sometimes are not very discernible, like the stimuli automatically produced by the passage of time; Darcheville et al., 1992; Marshall et al., 2014). The above feature makes these tasks quite challenging and demanding for a subject diagnosed with ADHD, and this difficulty often results in failure and other forms of social punishment that are responsible for their aversiveness for these tasks and, subsequently, their tendency to systematically avoid them.

Although cognitive and neurodevelopmental models stress the role of punitive conditions in the shaping of ADHD, they attribute the aversion and avoidance of complex and delay-related tasks to deficits in “executive functions” (e.g., inhibition, “working memory” deficits), often attributed to “neuropsychological” deficits (e.g., atypical reaction time variability) without specifying the behavior-environment interactions that alter the neurobiological structure and functions (e.g., Sjöwall et al., 2013; Sonuga-Barke, 2005; Sonuga-Barke et al., 2010). However, these deficits are behavioral components of the ADHD manifestation, not the actual cause. By attributing the disorder to the dysfunction of neuropsychological circuits or other internal states, the above and many other essentialistic approaches fail to provide practically serviceable formulations of its relation to individual experience. Unfortunately, these explanations complicate the experimental investigation of the problematic behavior-environment relations and their early identification. If a "symptom" is attributed to a dysfunction of a certain circuit, the circuit dysfunction cannot be observed until the symptom is manifested. Most importantly, essentialistic formulations impede the design and the implementation of interventions because they add a superfluous mediating stage between environment and behavior that cannot be directly controlled by the relevant educator, psychologist, caretaker or investigator.

In opposition to differential negative reinforcement of variability, differential *punishment* of variability combined with negative reinforcement of pattern repetition would be expected to *increase* stereotypy. Indeed, punishment/negative reinforcement preparations have frequently been observed to produce stereotypical responding, especially when punishment is not signaled by an external event (e.g., Dinsmoor, 1954; Sidman, 1953, 1962). In particular, different levels of behavioral diversity may be maintained or extinguished if they terminate or delay the presentation of a certain negative reinforcing stimulus from the context (e.g., Doughty et al., 2007). As a result, aversive stimuli may establish discriminative control over levels of topographical variability or stereotypy even when the relevant S^Ds are self-produced and/or cannot be observed by an independent party.

Indeed, it has been proposed that social as well as non-social negative reinforcement processes may play a primary role in the behavioral manifestation of Autism Spectrum Disorder

(ASD; Rapp & Vollmer, 2005). Of course, the removal of conditional or unconditional negative reinforcing stimuli cannot explain the whole behavioral spectrum in ASD, but it is plausible to hypothesize that the stimuli produced automatically in the emission of highly repetitive (or variable) patterns of behavior may acquire positive reinforcing potency (so-called *safety signals*, see below) when they terminate certain negative reinforcing stimuli (i.e., aversive events) in the environment. Subsequently, specific aversive events will acquire the discriminative function of *warning signals*, evoking the pattern of behavior (i.e., stereotypic repetition or differentiation from recently successful actions) that has mitigated similar annoyances in the past.

For example, in the study of Doughty and her colleagues (2007), stereotypic motor patterns of three human subjects diagnosed with severe-to-profound mental retardation were punished in the presence of certain contextual stimuli and not in their absence. While the repetitive action patterns continued to be emitted at high frequency in the absence of the warning signal for punishment, they were rarely emitted in the context in which stereotypy was punished. In time, the emission of stereotypic patterns terminated nearly contemporaneously with the presentation of the warning signal for punishment, indicating that this conditional negative reinforcer evoked (as S^D) the emission of acts incompatible with the emission of the punished stereotyped patterns-topographically distinct patterns the emission of which would automatically terminate any stimuli produced by stereotypy. The stimuli produced by the more variable patterns would then signal safety from punishment.

Presumably, if topographical variability in behavior patterning were to be differentially *punished* rather than negatively *reinforced* in a given context, it would become more stereotyped there, as stereotyped behavior automatically, instantaneously, and inevitably terminates the stimuli produced by more varied activity, stimuli that would have acquired conditional negative reinforcing potency (as warning signals for punishment) in this context. After the differential reinforcement of certain levels of behavioral diversity, response variability will likely fluctuate depending on the environmental stimuli associated with these levels.

Eye-movement patterning

The usual sensory domain of stereotypy in ASD (as well as in other neurodevelopmental disorders) is either motor or vocal, in the sense that these subjects tend to repeat certain kinetic or vocal actions with an extremely high frequency relatively to the average, neurotypical population. However, the category of motor stereotypies should include all forms of muscle activation of the human body, although some of them are very fine and brief such as those produced by the extraocular muscles which control eye movements. Of course, eye patterning stereotypy cannot yet be measured as easily as other forms of stereotypic motor activity, but this does not mean that it constitutes a distinct process.

Indeed, “absent, reduced or atypical eye contact,” which is included in the “poor nonverbal communication” criterion of ASD (DSM-5-TR; American Psychiatric Association, 2022), would appear to describe highly stereotypic eye contact. Both from experimental and therapeutic reports, it is well known that these individuals repeatedly look or avoid looking at certain stimuli or regions of their visual field (e.g., Manyakov et al., 2018; Sasson et al., 2008; Schwartzman et al., 2015). Thus, this “deficit” in eye contact behavior, which frequently leads to problems in their social integration and in many “cognitive” tasks that require eye movement responses (e.g., Falck-Ytter et al., 2014; Jones et al., 2016), can also be analyzed in terms of low eye-movement patterning variability due to differential reinforcement and punishment.

Altering eye movement variability levels as well as other forms of behavioral diversity, is an essential task of the researcher, the educator and the clinician. Specific contexts and schedules are usually arranged in order to increase the levels of variability both in experimental and applied settings. The most prominent arrangement is the implementation of the lag *n* procedure (see

Neuringer, 2002; e.g., Schwartz, 1982), which is in essence, a schedule of reinforcement where the reinforcer production depends on the topographic difference between the current form of response with the *n* previous response(s). For instance, when a lag 1 schedule is in operation, an emitted action pattern will produce a reinforcing stimulus only if that action differs in a specific topographic dimension from the previously-reinforced one. Similarly, in a lag 4 schedule, a response will produce a certain reinforcer only if that response differs in form from the *four* previous responses. Of course, what constitutes a “difference” between two actions is defined by the relevant researcher/practitioner prior to the schedule application.

Methods with similar effects on variability include novel response procedures (Pryor et al., 1969), reinforcement of least-frequently emitted response forms procedures (Blough, 1966), threshold procedures (Denney & Neuringer, 1998), as well as many others (see Neuringer, 2002). For example, in novel response procedures, a subject’s behavior is reinforced when a novel form is emitted for the first time ever (e.g., Eisenberger & Selbst, 1994; Goetz & Baer, 1973). On the other hand, in least-frequent response procedures (e.g., Shimp, 1967), the experimenter reinforces the most infrequently emitted response forms during the task. Similarly, in threshold procedures, the reinforcement of each response is based on its relative frequency. Therefore, the experimenter sets a specific relative frequency threshold prior to the initiation of the session, below which responses are reinforced (e.g., Doughty et al., 2013; Miller & Neuringer, 2000).

Although they have important technical differences, these methods share a common characteristic: they differentially reinforce forms of behavior that differ in specific aspects with some previous emitted behaviors and do not reinforce forms of behavior that resemble in certain aspects some previous emitted behaviors. Consequently, their reinforcement criterion is not static as in typical differential reinforcement procedures of behavioral dimensions such as force, duration and others. Rather, it is constantly redefined depending on the subject’s successful and unsuccessful behavior. Interventions based on these methods have proved effective in altering variability levels in typical and atypical populations, such as “depressed” individuals (e.g., Miller & Neuringer, 2000) or those on the “autistic spectrum” (e.g., Esch et al., 2009; Galizio et al., 2020; Silbaugh et al., 2020).

A different approach that is frequently used for modifying variability levels is the *overcorrection* procedure (Foxx & Azrin, 1973), which is more broadly used for reducing self-stimulatory behaviors (e.g., Lanovaz et al., 2013). Depending on the subtype of overcorrection (see Foxx & Azrin, 1973), this procedure may either “force” the subject to correct the consequences of his/her socially problematic behavior (*restitutional overcorrection*; e.g., Didden et al., 2005) or repeatedly practice socially appropriate forms of behavior after he/she emits an inappropriate behavior (*positive practice overcorrection*; e.g., Anderson & Le, 2011). For example, Anderson and Le implemented a positive practice overcorrection procedure to decrease vocal stereotypy in a seven-year old child diagnosed with autism. In particular, when the subject exhibited a stereotypic vocal response, he was physically prompted by the researcher to form a “silent” sign by putting his extended index finger in his lips 100 times. The experimenters applied consecutively different interventions (e.g., increased response cost, differential reinforcement of other behaviors), compared their effectiveness on vocal stereotypy levels, and concluded that overcorrection had the most beneficial outcome for the subject.

Even though it is argued that overcorrection may be a reliable method for reducing the extremely low variability levels of certain behaviors (Epstein et al., 1974; Simpson & Swenson, 1980), the actual processes that may lead to such a decrease are still under debate (see Miltenberger & Fuqua, 1980; Rapp & Vollmer, 2005). It has been proposed, for example, that that the possible physical contact between the experimenter/clinician and the subject may function as an aversive event that may evoke, as S^D, incompatible behavior (Miltenberger &

Fuqua, 1980). Another possible explanation that covers cases without physical contact is that the increased effort required after the stereotypic responses decreases their probability of occurrence. Subsequently, the relevant verbal commands of the practitioner may function as negative reinforcing stimuli, which are terminated by the non-punished responses (i.e., non-stereotypic responses).

This latter interpretation, which is inevitably based on the interpretation that overcorrection is a punishment-based procedure, seems particularly plausible (Miltenberger & Fuqua, 1980; Iwata, 1987). Indeed, the discriminative properties of punishment conditions may play a crucial role in the relevant reduced frequency of operant emission and its possible maintenance and generalization. This is quite clear when subjects tend to avoid the “threat of overcorrection” by emitting appropriate behaviors in the presence of the researcher and not in his/her absence. For instance, Rollings and his colleagues (1977) observed that one of their subjects (a 21-year-old mentally retarded male) tended to emit fewer stereotypic responses (head-weaving) depending on the proximity of the experimenter. As the distance between he and the experimenter decreased and the threat of overcorrection was increased, the emission frequency of behavior incompatible with head-weaving was observed to increase.

It is evident that punishing conditions do more than suppress behavior; they set the occasion for certain behaviors to be evoked and for others to be inhibited. This effect of punishment is usually overlooked in both experimental and clinical settings where punishment-based procedures are implemented because the mainstream theoretical and conceptual formulation that encompasses punishment, omits important operations that inevitably occur under punishing conditions. Therefore, before examining how aversive conditions may affect eye-movement patterning stereotypy or variability, it is essential to consider how punishing (as well as reinforcing) contexts alter the reinforcing potency of the consequences of behavior in general and analyze, both theoretically and conceptually, punishment and its possible effects.

Motivating Operations and Punishment

A controversial concept in behavior analysis that is used to describe and explain the evocative effect of punishing contexts is the *Motivating Operation Concept* (MOC; Laraway et al., 2014; Michael, 1982, 1988, 1993). Keller and Schoenfeld (1950) first introduced its progenitor term, *Establishing Operation* (EO), and extensively explored the theoretical basis of the concept of the so-called *drives* as a parameter that may affect operant behavior independently of the learning history of each organism. In the same textbook, the authors categorized *aversion* as an establishing operation and stated the criteria that need to be met in order to name a stimulus aversive: the termination of this stimulus should *strengthen* the emission frequency of the action preceding it, and the *production* of this stimulus should decrease the emission frequency of the act preceding it. The above two criteria match those of stimuli that function as “negative reinforcers,” but the influence of certain aversive stimuli (e.g., a loud sound) on behavior does not depend solely on the differential reinforcement history of the subject.

For example, an electric shock presentation, in addition to its respondent and negative reinforcing nature, may favor the emission of certain forms of behaviors while inhibiting the emission of others. Any behavioral change that may come along after the shock presentation that cannot be attributed directly to a reinforcement history could be a product of a motivating operation. For instance, an aversive stimulus may favor immobility or “freezing” in certain organisms or shaking in others, even though none of these behaviors is negatively reinforced. Moreover, increasing the aversive stimulation would presumably increase the frequency of occurrence of that behavior, and decreasing the stimulation would likely decrease it. Based on these observations, exposure to aversive stimulation is also considered an establishing operation.

Lastly but not least importantly, they also suggested that the response rate may not be the only dimension affected by the EOs and noted that these operations might have various behavioral effects that can be observed only if these variables are appropriately measured. Topographical stereotypy or variability could be one of these dimensions.

In the most well-known paper regarding MOs, Michael (1982) reintroduced the term “Establishing Operation” and suggested that EOs have two distinct effects on behavior: they momentary increase the reinforcing effectiveness of an object or event and evoke the behavior that has been followed in the past by that object or event. He later named the former, *reinforcer-establishing effect*, and the latter, *evocative effect* (1993). For example, depriving a child of food would increase the reinforcing value of food (reinforcer-establishing effect) and evoke the behavior that may produce it, such as opening the fridge or asking his parents to prepare a meal (evocative effect). Most importantly, he attempts to delineate the difference between S^Ds and EOs in order to facilitate the classification of these events. In a differential reinforcement process, the relevant behavior produces a specific consequence and occurs with higher frequency in the presence of the S^D, in comparison with its absence. However, Michaels stresses a commonly overlooked fact: both in the presence and the absence of the S^D, the consequence has the same reinforcing value; that is, no changes occur in the effectiveness of the reinforcing stimulus. Based on this note, he contends that deprivation (or any other EO) could not function as S^D because in the “absence” of deprivation (or of any other EO), the relevant consequence (i.e., food) has not equal reinforcing potency as in its “presence.” Subsequently, he suggests that the lower frequency of food-seeking in the absence of deprivation indicates a change in the reinforcing value of food rather than an S^Δ effect. In the opinion of Michael, this distinction may help separate S^Ds and EOs.

Then the author extends the preceding rationale to an aversive stimulation context. In a shock escape procedure, the subject may terminate the shock by pressing a lever. It is generally accepted that the shock has discriminative properties because in its presence, the lever pressing occurs very frequently relative to its absence due to the shock removal. Consequently, the absence of the shock is considered to function as S^{Δ} for level pressing. However, to function as S^{D}, the lever pressing should be differentially reinforced during the shock by shock termination compared to shock absence. This is not technically possible, according to Michael, because during shock absence, the lower frequency of lever pressing cannot be attributed to extinction of the lever pressing because there is no aversive stimulus that can be practically removed. Thus, he recommends that the aversive stimulus exemplified above, as well as many other negative reinforcing stimuli inherent in basic experimental paradigms, should not be considered as discriminative stimuli but as establishing operations since they do not fulfill the criteria of the former, but they do for the latter: they increase the reinforcing effectiveness of the termination of the negative reinforcer, and they increase the probability of the class of responses that terminate this type of negative reinforcers.

Moreover, in this concept, establishing operations are divided in unconditioned and conditioned operations, where the former includes operations that depend on the organism's phylogenetic history such as food deprivation and satiation or drug effects, and the latter includes operations whose motivating effects are a product of learning procedures. Conditioned establishing operations (CEOs) are then further divided into three distinct subtypes according to their behavioral origin. The first of them is called *surrogate* CEO (e.g., Torisi, 2013) and results from respondent conditioning between a neutral event and an Unconditioned establishing operation (UEO; or another CEO). For instance, certain drug effects may be considered as an UEO (for food intake, social interaction, recall tasks, etc.) and the respondent pairing between the tools of administrating these drugs and their effect may result in a “transfer” of the establishing properties of the drug to the tools. In other words, the presentation of the tools apart from the capacity to elicit certain physiological responses will also function as a CEO.

The second subtype is called *reflexive* CEO (e.g., Carbone et al., 2010). In this type of operations, the presentation of a certain stimulus establishes its own removal as reinforcement and evokes the form of responses that remove it. For example, in the warning stimulus avoidance procedure described above, the presentation of the warning stimulus functions as a reflexive CEO by establishing its termination as reinforcing event and subsequently increases the frequency of responses that terminate it (i.e., the lever press in the aforementioned example).

The third subtype which is called *transitive* CEO (e.g., Belfiore et al., 2016) refers to operations where the presentation of certain stimuli alters the reinforcing or punishing potency of another stimulus and subsequently evokes or abates the relevant behavior that produces or remove this second stimulus. Michael refers to it as “a form of conditional conditioned reinforcement” but still supports the idea that it is not a matter of discrimination but rather than that of an establishing operation. The issue is further perplexed as he suggests that in an avoidance procedure, the warning stimulus functions as a reflexive CEO, but simultaneously, it functions as a transitive CEO evoking the operant chain of the level press (the response that removes the warning stimulus). Considering that many avoidance procedures elicit fear and anxiety responses, it may be hypothesized that a certain stimulus may function as surrogate, reflexive and transitive CEO simultaneously. The lack of parsimony of this view will be discussed later.

Since then, the MOC received several conceptual criticisms (e.g., Catania, 1993; Cherpas, 1993; Hayes & Fryling, 2014; Lotfizadeh et al., 2012; McDevitt & Fantino, 1993) and underwent terminological refinements (e.g., Laraway et al., 2001, 2003, 2014) but the definition of the MOs effects remained relatively unaltered: MOs are said to influence the capacity of operant consequences to alter the strength of future behavior (the value-altering effect), and (b) change the current strength of behaviors related to the consequences affected by the MO (the behavior-altering effect). Although it is tempting to use the MO terminology in order to describe and interpret behavioral manifestations that occur under punishing conditions, including the evocative effect of certain avoidance or escape responses, a main issue arises by the use of this MO concept. Specifically, the role of relevant S^D is generally undervalued, especially when these discriminative stimuli are not publicly observed, leading some behavior analysts to assume a direct link between MOs and operant responding (e.g., Laraway & Snycerski, 2019; Lechago, 2019; Miguel, 2019). However, this assumption inevitably leads to neglecting or at least underestimating the role of automatic stimuli produced in a certain context. These, often private stimuli and, subsequently, difficult to observe and control events, are vital in many behavioral settings (e.g., Mellon, 2013a).

Punishing conditions are one of the contexts where the unawareness of the role of the relevant automatic stimuli and the assumption of a direct relationship between MOs and behavior may lead to problematic or at least not adequately comprehensive behavioral analyses; self-produced negative reinforcers may evoke, as S^D, the emission of acts that have successfully terminated them in the past. Besides this, as it has been repeatedly suggested since then (e.g., Catania 1993; Edwards et al., 2019a, 2019b; Edwards & Poling, 2020; Poling et al., 2017), many of the operations included in the CEOs list can be explained adequately by the respondent and operant principles already existing in the repertoire of the behavior analyst. Therefore, it seems fruitless to attempt explaining and interpreting the motivating effects of punishment in terms of conditioned motivating operations. In order to provide a more comprehensive and eventually effective description of the relation between eye movement, as well as others forms of behavior, and stereotypy and variability, punishment procedures should be analyzed in a more molecular manner.

Punishment: Process or Operation?

The most common way to change an ongoing schedule is by increasing or decreasing the frequency of reinforcement of the target behavior (Ferster & Skinner, 1957). Another way a schedule may change is by configuring punishment when the target responses fail to occur. For example, instead of increasing the frequency of social reinforcer deliveries for reading, parents may present social and non-social negative reinforcers as a consequence for their child's off-task behavior. Assuming that socially appropriate behaviors are incompatible with the inappropriate, increments in the negative reinforcing effectiveness of the former may reduce the frequency of the latter.

However, in the above example, the two forms of behavior (socially appropriate and inappropriate) compete with each other, and punishment of one behavior is inevitably (and inversely) related to the frequency of the second. A long time ago, it was shown that punishment may have various effects on behavior even when there is a large temporal (and subsequently behavioral) gap between punishment and behavior (Camp et al., 1967). Furthermore, punishment has also been linked with a rise in aggressive behavior, which is modulated by an increase in the reinforcing effectiveness of the automatic stimuli produced by aggressive behaviors (Ulrich & Azrin, 1962).

What is important here is that punishment may evoke such behaviors even if it is irrelevant to the operant chain that leads to the production of punishment. For example, in their well-known experiment, Azrin, Hutchinson and Hake (1966) trained pigeons to peck a key in a multiple schedule where periods of continuous reinforcement (CRF) of key pecking were alternated with periods of extinction (EXT). On the other side of the experimental chamber, another pigeon (target-pigeon) was fastened and relatively immobilized by a band. Experimenters observed that subjects attacked target-pigeons when the component was changed from CRF to EXT, and the aggressive behavior could not be attributed to other factors (prior history, signaled or unsignaled EXT, or superstition reinforcement). In a succeeding experiment of the same study, some subjects attacked a stuffed pigeon which was placed in the same position as the live targets. In both cases but especially in the latter, it is obvious that the aggressive behavior was irrelevant with the operant chain that leaded to reinforcement and punishment. However, it is apparent that subjects' course of action was affected drastically by the punitive event.

A usually ignored fact in experimental paradigms illustrating "induced" aggression is that together with the occurrence of aggressive responses there is inevitably an increase in the variability levels of subjects' behavior. Although it is difficult to dissociate between extinction bursts and induced aggression, it is reasonable to assume that attacking is mainly a result of the schedule transition. Thus, it could be argued that at least in the initial stages of punishment production, the increasing tendency to behave aggressively is unavoidably accompanied by an abrupt increase in the variability levels of behavior even though the aggressive responses might be highly stereotyped. Of course, this is not proof of a direct relationship between punishment and variability but it is indicative that the presentation of a negative reinforcer (e.g., the schedule change in the above experiment) or the removal of a positive reinforcer may also change the behavioral variability cascade at least in the initial stages of their occurrence.

A clearer (but still indirect) connection between variability levels and a "pure" motivating operation (deprivation) was observed a long time ago by Winnick (1950). In particular, by studying potential discriminative properties of automatic stimuli produced by motivating operations, she observed that rats exhibited higher variability levels when being food-deprived. However, variability levels in her study were obliquely estimated. Winnick calculated the time emitting an avoidance behavior compared to other irrelevant behaviors, and she noted that deprived rats (compared to food-satiated) spent more time alternating between the avoidance response (panel pushing) and other behaviors in the chamber. She then interpreted this difference as a "greater amount of activity" of hungry rats compared to the satiated rats. However, both in the above experimental context as well as in other avoidance paradigms inside or outside the laboratory, variability increases/decreases are not a direct result of the punishment application. In order to understand the possible relation between variability and punishment, we need to elucidate the processes involved in the former and, eventually its effects on behavior.

Prominent behavior analysts have defined punishment as a process (e.g., Azrin & Holz, 1966; Catania, 1998) or contingency (e.g., Pierce & Cheney, 2013) that results in decreases in the frequency of behavior. For example, in widely-read textbook "Applied Behavior Analysis" written by Cooper, Heron and Heward (2020), the authors state: "Punishment has occurred when a response is followed immediately by a stimulus change that decreases the future frequency of that type of behavior" (p. 365). Similar definitions of punishment can be found in the majority of the well-known behavior analysis textbooks (e.g., Donahoe & Palmer, 1994; Leslie, 1996). All of them are based on the definition of punishment established by Azrin and Holz (1966). However, Skinner (1953; as well as Keller and Schoenfeld, 1950 and Sidman, 2000) did not define punishment in that way. Specifically, even though he recognized that punishment might lead to decreases in the rate of behavior, he defined punishment as a *procedure* where certain responses are followed by the removal of a positive reinforcer or the presentation of a negative reinforcer. No reference was made to the subsequent change in the frequency of the relative behavior. Ultimately, when focusing on the effects of punishment on behavior, Skinner does not presume; rather, he asks (1953, p. 185): "What is the effect of withdrawing a positive reinforcer or presenting a negative"? As Holth (2005) correctly pointed out, Skinner's definition encourages the conceptual as well as the practical analysis regarding the possible effects of punishment. Punishment is a complex procedure and not just a reduction in response rate. It may involve respondent as well as operant mechanisms (e.g., Camp et al., 1967), and the identification and analysis of these underlying mechanisms may provide a helpful framework for understanding possible relationships between punishment and variability levels.

According to Skinner, punishment may lead to a frequency reduction of the target behavior by three different effects. Firstly, punishment can elicit responses that may interferere with ongoing operant behavior. For example, when a teacher punishes with loud voices chatting between classmates, increased sympathetic activity (e.g., increased pulses and blood pressure, decreased saliva flow and others) and certain emotional responses (e.g., anxiety, fear, arousal and others do not favor the continuation of chatting. Therefore, because those elicited responses are somewhat incompatible with the punished behavior, the frequency of the latter may be reduced. The second effect is based on the respondent conditioning of the previously punished behavior with the responses of fear, anxiety and other similar reactions. Due to the pairing of the stimuli of punished behavior with certain emotional reflexes, stimuli produced in the emission of the punished behavior may elicit conditioned responses systematically, even though the behavior is not punished every time it occurs. Thus, similarly with the foregoing effect, to the extent that these conditionally elicited responses are incompatible with the punished act, its rate of emission may be reduced.

The third effect, which is the most crucial in the operant level, arises from the previous effect. In particular, when the stimuli accompanying punishment acquire the potency to elicit certain reflexes of anxiety, fear or others, they simultaneously function as negative reinforcers or as commonly named warning stimuli. Therefore, actions incompatible with those that produce the conditioned aversive stimuli will be reinforced by the termination of these warning stimuli.

Inevitably, repeated exposure to punishment conditions may establish avoidance behaviors that can be evoked even in the absence of external and publicly observable warning stimuli (e.g., Sidman, 1953, 1962; Dinsmoor & Sears, 1973). An extension of third effect was later proposed (Dinsmoor & Sears, 1973; Dinsmoor, 2001a, 2001b), suggesting that the stimuli produced by the non-punished behaviors acquire the potency to elicit responses of alleviation or safety due to their pairing with the relieving termination of the warning signals. Subsequently, they function as positive reinforcing stimuli (i.e. safety signals), evoking the emission of the non-punished behaviors that produced them.

To sum up, punishment as a procedure may have four distinct effects, which can lead to a reduction of the frequency of the punished behavior (Mellon, 2013a). Firstly, it may elicit reactions that can be incompatible with the punished responses; secondly, stimuli that accompany the punished behavior are conditioned to elicit the preceding reactions; thirdly, after the preceding pairing, the stimuli produced by the punished behavior acquire negative reinforcing properties (function as warning stimuli) that evoke incompatible actions as discriminative stimuli, and lastly, the stimuli produced by the non-punished behaviors acquire positive reinforcing properties (function as safety signals) reinforcing the emission of actions incompatible with the emission of the punished response form. This molecular analysis (Disnmoor, 1954, 1955; Mellon, 2013b; Sidman, 2000) directly and comprehensively addresses the above question raised by Skinner almost 70 years ago.

Therefore, it is reasonable to expect that the exposure to punishment conditions may favor the establishment of elicited and evoked responses that are incompatible with the punished one. For example, a child may shout, attack or even injure herself when her parents grab her tablet from her hands if these behaviors have been negatively reinforced by the termination of the presence of her parents (and positively reinforced by the retaking of the tablet). One challenge, both in experimental and applied settings is that the behaviors that remove self-produced warning stimuli may differ significantly in their topography. In the previous example, the child avoids systematically “losing” her tablet either by shouting or attacking, when a warning signal for tablet loss occurs, for instance, when her mother looks at her disapprovingly. Although the loud voice and the somatic attack are functionally equal (they have both removed the same conditional negative reinforcers in the past), they differ in topographical level. Yelling is a vocal response, whereas a somatic attack is a gross skeletal motor response. In many punishment contexts, the relevant evoked responses can have different forms ranging from inactivity and withdrawal to aggression and self-injury. This event may sometimes hinder the prediction (as well as the control) of certain forms of avoidance and escape behaviors, especially in conditions where there is no clear-cut warning stimulus in the environment and various forms of responses may be (adventitiously or not) negatively reinforced.

However, the difficulty in the prediction of the form of the avoidance response does not mean that the ultimately evoked behavior is random or, at most, a “side effect” of the punishment procedure. Aversive stimuli may systematically lead to the emission of behavioral patterns that have repeatedly terminated similar threats in the past and not just to other random patterns that were chosen independently of their consequences. As noted above, for example, Fonseca Junior and Leite Hunziker (2017) implemented an experimental design where the subjects (rats) could avoid shocks by producing sequences of three lever presses distributed over two levers on the condition that the last sequence differed from one (lag 1), two (lag 2) or three (lag 3) previous sequences. Levels of variability (measured by U-value and relative frequency of “successful” avoidance behavior) were compared with a yoke condition (with the same reinforcement frequency and distribution), and it was clear that variable patterns of behavior were more frequently emitted when variability was a requirement of the schedule of reinforcement. In other words, in the presence of an aversive stimulus, variability levels tend to increase when such variability has terminated similar aversive stimuli in the past. In reversed order, relatively high stereotypy levels of a particular form of behavior may be maintained when doing so eliminates a threat in the environment. In both cases, the efficacy of the avoidance behavior depends on the differential reinforcement of either variability or stereotypy, respectively.

Aims of the study

In both above-mentioned and by other studies described previously, it is evident that punishing conditions may establish discriminative control over non-human (e.g., Fonseca Junior & Hunziker, 2017) as well as human (e.g., Doughty et al., 2007) variability levels. However, by focusing solely on the reduction in the frequency of emission of a response, discriminative as well as other effects of aversive events can be easily neglected, especially when these effects may affect temporally distant links of the operant chain. Therefore, the aim of the first experiment was to isolate the pre-established discriminative effects of social punishment levels of variability, in the eye-movement patterning of neurotypical adults. A serial visual-motor patterning task was designed to ensure that the levels of variability patterning were neither targeted for differential punishment nor for differential reinforcement. Thus, possible and systematic alterations in subjects' variability levels, evoked by the punishment of functionally unrelated behavior, would be plausibly attributed to the discriminative control of the punishing conditions themselves.

Specifically, experimental subjects performed a two-link task in the form of an operant chain. In the first link, they were free to produce either competently stereotyped or somewhat variable fixation patterns by consecutively fixating on four distinct visual stimuli on a computer screen; no aversive consequence were produced in this first task; they had to focus once on each stimulus in any order that they chose, repeating or not repeating, previously reinforced patterns. In the second link, their task was to search and detect a small change in their visual field.

Throughout the three phases of the experiment (ABA’ or reversal experimental design), correct detections were reinforced with points. Regarding false detections, these were neither punished nor reinforced in the first (baseline phase) and the third phase (reversal phase). Exclusively, in the second phase (manipulation phase), failures to detect the visual change were *punished* with point *loss*, accompanied by a familiar gaming-failure sound. Neither link explicitly provided differential reinforcement or punishment for levels of stereotypy/variability for any aspect of prior visual-motor activity. Thus, we tested whether the punishment of detection failures in the first link evoked the emission of inoperative stereotypy in the second link. Any possible alteration in the variability levels in the first link might then be plausibly interpreted to reflect a pre-experimental history of punishment of variability and consequent negative reinforcement of stereotypy in similar settings.

In other words, the purpose of the first experiment was to test whether the punishment of detection failures systematically altered subjects’ tendency to replicate from recently emitted visual-motor action patterns, when such changes in topographical variability were independent to experimenter-mediated reinforcing contingencies of any form of differential reinforcement and extinction. Such a test case might prove helpful in the scientific interpretation of the provenance of otherwise enigmatic non-adaptive or maladaptive stereotypy or variability, as well as the resistance to change of reinforced topographical auto-parity or disparity when ineffective or punished.

Similarly with the rationale of the first experiment of the present study, the second experiment attempted to isolate this pre-established evocative effect of punishment upon variability levels on human participants. The visual-motor search task was identical to the one used in the previous two tasks, but subjects were exposed to different learning contingencies in the first link of the operant chain. In particular, in order to proceed to the second link of the operant chain (i.e., visual search task), participant was required to produce an eye movement pattern that differed from the last emitted pattern (technically, a lag 1 schedule). This experimental configuration was designed to address a basic issue in the results of the first experiment, wherein some of the subjects exhibited high baseline levels of visual-motor stereotypy that could not be further increased (i.e., ceiling effect) when punishment occurred in the manipulation phase.

Again, no differential reinforcement or punishment of stereotypy or variability was programmed in the first link of the operant chain; rather, perceived second-link detection errors in the second phase were punished (only in the experimental group). By implementing this configuration, possible systematic changes in ocular-movement patterning variability levels should be attributed to the evocative effect of the second-link punishing condition. Most importantly, if the direction of variability changes (either increase or decrease) proves to be similar to the first experiment, then it should be concluded that punishment, as a motivating operation, directly evokes stereotypic responding. However, if variability changes have not the same direction with the first experiment then it should be concluded that the evocative effect of punishing conditions is somehow mediated by the learning history of the subject within the experimental procedure due to experimentally acquired stimulus control processes.

Experiment 1

Method

Subjects

Twenty-two subjects participated voluntarily in this study. Sixteen were first and second-year undergraduate psychology students; none were familiar with behavior analytic research on the determinants of topographical variability or the effects of punishment. They ranged in age from 19 to 27 years (M = 21.3); thirteen self-identified as female and nine as male. All subjects affirmed normal or corrected vision (with eyeglasses or contact lenses). Prior to the onset of the experimental procedure, informed consent was obtained from each participant (see Appendix A); they were fully debriefed after their participation. All procedures performed in the study were in accordance with the ethical standards of the institutional and national research committees.

Equipment and apparatus

The study was conducted in the Laboratory of Experimental and Applied Behavior Analysis of the Department of Psychology and Social Sciences, at Panteion University, Athens, Greece. The experiment took place in a sound-attenuated 1.2 × 2.0 × 2.3 m chamber with a small window in the back right side and illuminated by a warm white bulb. The experimental chamber also contained a desk and a chair. Upon the desk, there was a 21.5-inch computer monitor (Samsung S22F350) with a screen resolution of 1920 x 1080 pixels and a frame rate of 60Hz, a pair of speakers (Creative A120) and a silent mouse (Logitech M220).

Subjects performed a computer-based task running custom software written in GoDot version 3.1.2 and their eye movements were recorded with an infrared eye tracking device (The Eye Tribe; Dalmaijer, 2014; Ooms et al., 2015) with a sampling rate of 60Hz and an average error of 0.5° to 1°. The eye-tracker was placed on a tripod below the monitor, pointing to the eyes and participants were instructed to position themselves at a distance of about 60 cm from its center. Figure 1 shows the experimental setup.

Figure 1

Photo of the computer and eye-tracker setup inside the experimental chamber

Procedure

In the beginning of the study, subjects were welcomed by the experimenter. Afterward, they were instructed about the experimental procedure (calibration and task) both orally and by the use of a laptop computer outside the experimental chamber. The instructions (translated into English) were as follows:

> You are about to participate in a study concerning attention and perception, in which you will play a computer game. When the video game starts, in the upper part of the screen

> you will see your points total. Your goal is to earn as many points as possible. Later you will receive your ranking among the other study participants.
>
> In the beginning of the task you need to fixate your gaze on the cross that appears in center of the screen. When the cross disappears, four black dots will appear on the screen; you need to fixate at least once on each one of the four black dots in any order that you wish. Every time you look at a black dot, you will hear a tone. Looking at the same dot for a second time will have no effect. When you have fixated once on all four black dots, an unlocked padlock icon will appear; then the attention and perception task begins.
>
> When the padlock disappears, a small white dot will momentarily appear inside one of the four black dots; to score points, you need to click with the mouse the black dot where the white dot appeared. Because the white dot will appear and disappear very quickly, you might miss it; if so, you will need to guess where it had appeared. When you make your choice, you and will see the results and then the next trial begins. The task lasts approximately 25 minutes. Is that clear?

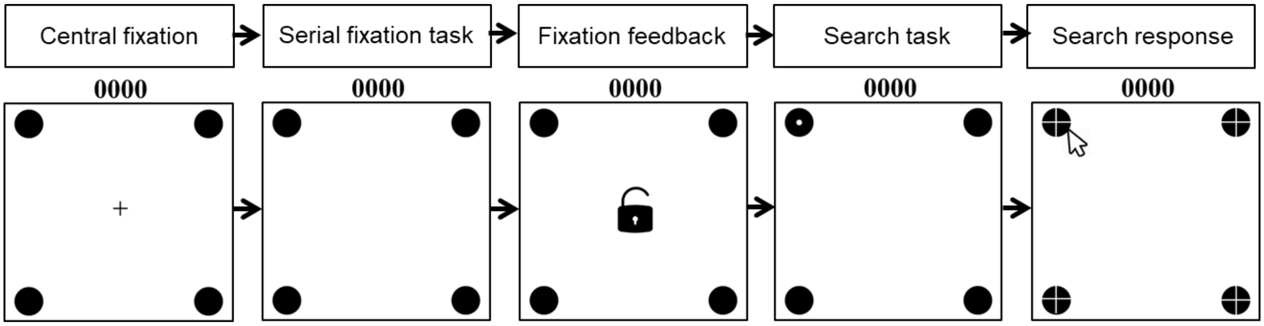
When the subjects responded positively, they entered the experimental chamber, sat in a comfortable chair and underwent an eye-tracker calibration procedure where they had to sequentially fixate on 16 points of the screen in random order. The background of the calibration screen, as well as the fixation points, had similar technical characteristics with the main task (e.g., color, dimensions and others; see below). Acceptable levels of accuracy error were < 1°. Although a 23rd subject did not proceed to the experimental “task phase” due to a high error of calibration accuracy (> 1°), the vast majority of the participants had an accepted calibration of <0.7° error. Calibration was followed by a short practice session of the experimental task, with verbal feedback from the experimenter in order to help subjects familiarize themselves with its eye movement components. Ten “warm-up” trials were then performed in the absence of verbal prompts from the experimenter.

Task

The experimental task was divided in two distinct subtasks, forming a two-link operant chain: a serial fixation patterning task and a visual search task. Figure 2 illustrates the structure of the task (for a colorized version, see Appendix B).

Figure 2

Illustration of the task components in Experiment 1



Note. Visual stimuli presented during the course of the task (from left to right): central fixation (300 ms); serial fixation patterning task (300 ms at each of four fixation points in any order); fixation completion feedback (1.5 seconds with “unlock” sound); search task (with target white dot in the upper left-hand corner); and correct mouse-click detection response. The running points total appear in the upper part of the screen.

Throughout the procedure, a points counter (starting from zero) appeared at the top of the screen in white, green or red font (see below), indicating how many points have been earned so far. As mentioned above, earned points were the conditional reinforcing stimuli used in this task, as subjects were instructed to gather as many points as possible. At the outset of the patterning task, a 1 x 1 cm black cross was presented in the center of the screen, along with four black fixation points (or “dots,” with $r = 0.5$ cm) equidistant from one another near the four corners of the screen, forming a conceivable square. The background of the screen was achromatic grey (same as in the calibration procedure; see Appendix B for original screenshots of the task).

Each trial began when subjects fixated their gaze within an area of 3 x 3 cm centered on the cross for 300 ms, resulting in a brief gaming “click” sound (40 ms), the disappearance of the cross, and the initiation of the first-link task of the operant chain, the serial fixation task. It should be noted that eye movement capture areas were somewhat larger than target stimuli to reduce accuracy and precision error variance. After the disappearance of the cross, a visual fixation on any of the four dots for 300 ms produced a 500 ms auditory feedback tone without normative “meaning” (i.e., a “neutral” tone). Repetition or maintenance of gazing (after the feedback tone) on a certain dot did not produce any other visual or auditory stimulus. When the subject had fixated on each of the four dots, a transition to the second-link task of the operant chain, the visual search task, was produced, signaled by an open padlock icon (see Figure 2) and a relevant gaming “unlock” sound (600 ms).

Although the order of fixations across the four dots in the serial fixation patterning task (upper left, upper right, lower left and lower right) had no scheduled effect, the four-dot patterns produced by the subjects in each trial were recorded and provided the behavioral responding basis for measuring and assessing levels of topographical stereotypy or variability evoked under punishing conditions as well as by a return to non-punitive baseline conditions (see below). In other words, the variability of the serial fixation patterns in the first-link task was the dependent variable of the experiment.

After 1500 ms following the disappearance of the unlocked padlock icon, only four black dots remained in the corners of the screen and the second-link visual search task began. In 50%

of the trials (approximately 50%, as the type of trials was randomly determined), a small white dot (r = 0.1 cm) appeared inside a randomly-determined black dot within an average of 500 ms and with a range from 250 to 750 ms. After the disappearance of the white dot, a thin white cross appeared in each of the four black dots, signaling that the subjects had to choose by pressing the left mouse button, the black dot in which, in their judgment, the white dot had just appeared. Note that due to low sampling rate of the eye tracking device used, levels of eye movement variability in the second-link task of the operant chain could not be efficiently recorded.

Regarding the schedule of reinforcement of accurate and inaccurate detections of the location upon which the white dot had just appeared, correct choices were reinforced with 10 points added to the counter, throughout the three experimental phases (explained below), accompanied by a 600 ms sound normatively associated with point gain in video gaming and a concurrent 600 ms change in the font color of the point counter from white to green (RGBA [0, 255, 0]).

However, contrary to the subjects' expectation, in the other 50% of the trials, the white dot did not appear at all. In these trials, the crosses that otherwise followed the white dot's offset appeared after the same average delay (500 ms with a range from 250 to 750 ms), indicating to the subjects that the white dot had actually appeared, but that they had failed to detect it. In cases in which the subjects (presumably) failed to detect the white dot, they were instructed to guess where it might have appeared, and they earned points with a 25% probability of choosing the appropriate black dot which was again determined randomly among the four available.

The purpose of this deception was to ensure that a relatively significant and stable number of detection errors would be made by the subjects in each phase, as few errors were expected on the other 50% of the "typical" trials. The subjects' false idea that they had failed to detect the white dots in these deceptive trials was further enhanced by the variable duration of their presentation when they actually appeared (averaging 500 ms), giving the impression that the detections of the relatively shorter-duration white dot presentations were nearly missed.

Inaccurate detections (i.e., errors) of the first phase did not produce any point changes; they were simply followed by the initiation of the next trial. However, in order to evaluate the evocative effect of a punishing context on variability levels of a different link of the operant chain, an ABA’ reversal design was implemented by introducing a point-loss punishment procedure for detection errors in the visual search task in the second phase (phase B or manipulation phase); a return to baseline conditions ensued in the third phase (phase A’ or reversal phase). Specifically, in phase B, errors (actual and perceived) in the second-link visual search task were punished with a loss of 10 points signaled by a 600 ms change in the font color of the points counter from white to red (RGBA [255, 0, 0]) and a more intense (75 dB) and extended (600 ms) sound associated with failure in video-gaming. In the reversal phase (A’) point-loss punishment contingency was removed, and detection errors only produced the initiation of the next trial as in the baseline phase. As mentioned above, correct responses (both detections and guesses) were reinforced with the same schedule of reinforcement throughout the experiment. Each phase included 60 trials (180 trials in total), and transitions between phases were not signaled by any stimulus, except the change in the point-loss consequences.

As it is true for several similar tasks that require high alertness and sustained attention skills as well as repetitive eye movement responses (e.g., Körber et al., 2015; see Warm et al., 2018), it was possible that extended exposure to a task to the above-described task might lead to systematic fatigue-based changes in ocular responding variance over time independently of the relevant experimental manipulation. To test for that possibility, a second “control” group of subjects was introduced and exposed to the same task duration and point-reinforcing contingencies, but in the second phase, there was no-point-loss punishment (i.e., AAA conditions as opposed to the ABA’). Subjects were randomly assigned to one of these groups prior to the experimental procedure.

Four dependent measures of stereotypy/variability in fixation patterning were used; first, the absolute number of topographical distinct patterns produced in each phase, with higher numbers indicating higher levels of visual-motor variability. Then the relative frequencies of emission of the most-frequently emitted pattern (“most prevalent”) and the relative frequency of emissions of the sum of the *two* most-frequently emitted patterns (“two most prevalent”) were calculated in a given phase. In both of the above measurements, higher values indicated higher levels of visual-motor stereotypy. It should be noted here that as these relative frequencies were calculated separately for each experimental phase, the specific fixation patterns that were most frequently produced by the subjects most frequently were free to vary across phases. In order to cope with this issue, U-values were calculated as they are sensitive to change in the most prevalent sequence (e.g., Neuringer, 2002; see also Kong et al., 2017). The following formula was used:

$$U\text{-}value = -\sum_{i=1}^{\beta} \frac{a_i \times \log(a_i)}{\log(\beta)}$$

Values of U vary between 0 (repetitive responding of a certain pattern) and 1 (equal distribution of the 24 patterns that could be produced in this context), with higher values indicating higher overall variability. However, two issues arise from using of U-values as a measure of variability that are worth mentioning. Even though U-value is a relatively accurate molar measure of operant variability and takes into account possible changes in the most prevalent emitted pattern, it does not capture high-order stereotypy responding (e.g., repetitive alternations between two or three sequences), and most importantly, it can be biased when a different number of the available responses is emitted across the phases (Kong et al., 2017). Because of this, it will be used only to compare responding within/between groups and not within/between subjects. In any case, U-value can still help identify (at least partially) possible changes in the levels visual-motor stereotypy/variability levels.

Statistical analysis

Descriptive and inferential statistics were done using Microsoft Excel v.14 and IBM SPSS Statistics Version 26. Effect sizes for Friedman's ANOVA are reported as Kendall's W (Coefficient of concordance), which value ranges between 0 and 1 and its interpretation is based on Cohen's guidelines: 0.1 is considered a small effect, 0.3 is considered a moderate effect and 0.5 and above is considered a strong effect.

Results

In order to allow comparisons between conditions as well as between groups, the total trials (180) of the control group were divided into three unsignaled or "dummy" phases of 60 trials each. In analyzing the data, it was essential to confirm at the outset that each participant performed relatively well in the task, in the sense that extremely low performances compared to the mean and/or across conditions might indicate either lack of interest in the task or an unidentified vision deficit. Subjects' performance was computed by the percentage of correct responses in the trials where the white dot actually appeared (50% of total trials). All subjects had relatively the same percentage of correct responses across conditions indicating that they were adequately effective and vigilant throughout the task. The mean percentage of correct responses in the "visible white dot" trials was M_1 = 89.9% (SE = 2.8%) in the baseline phase, M_2 = 94.9% (SE = 1.5%) in the manipulation phase and M_3 = 95.3% (SE = 1.8%) in the reversal phase for the ABA' group. For the control condition, the respective percentages were M_1 = 89.7% (SE = 2.8%)

in the first phase, M_2 = 93.8% (*SE* = 1.9%) in the second phase and M_3 = 92.5% (*SE* = 2.9%) in the third phase. At the individual level, no subject had an atypically low accuracy score in any phase (range 74.2-100% for the experimental and range 68-100%, for the control group). Lastly, a high-order stereotypy control (i.e., alternating between two or three patterns) was performed with no significant results in any of the subjects.

Furthermore, it was necessary to ensure that points earning momentum was inhibited in the second phase for the experimental group (point-loss phase) but not for the control group. In the experimental group, the average earned points were M_1 = 345.5 with *SE* = 15.3 in the baseline phase, M_2 = 127.3 with *SE* = 28.3 in the manipulation phase and M_3 = 349.1 with *SE* = 13.5 in the reversal phase. In the control group, the average gained points were 339.1 with *SE* = 15.2 in the first phase, 352.7 with *SE* = 14.5 in the second phase and 349.1 with *SE* = 14 in the third phase. By inspecting Table 1, it is obvious that subjects of the experimental group collected markedly fewer points in the manipulation phase compared to the baseline and the reversal phase. This difference was also statistically reliable when assessed by a Friedman test (parametric assumptions were not met) indicating a significant effect on condition type on points earnings, $\chi 2(2) = 16.545$, $p < .001$, $W = .752$, representing a large effect size. Post hoc Wilcoxon signed-rank tests using Bonferonni-adjusted alpha level ($\alpha = .016$), showed that subjects earned significantly more points in the baseline phase (*Mdn* = 350, *IQR* = 80) compared to the manipulation phase (*Mdn* = 80, *IQR* = 160, *Z* = 2.937 , *p* = .003), indicating a large effect size (*r* = .63) and more points in the reversal phase (*Mdn* = 340, *IQR* = 60) compared to the manipulation phase (*Mdn* = 80, *IQR* = 160 , *Z* = 2.938 , *p* = .003) indicating again a large effect size (*r* = .63). Statistical difference between baseline (*Mdn* = 350, *IQR* = 80) and reversal phase (*Mdn* = 340, *IQR* = 60) was not significant.

However, no significant effect of the condition series (1^{st}, 2^{nd} and 3^{rd}; i.e., trials 1-60, 61-120 and 121-180 respectively) on point earnings was found for the control subjects, F(2, 20) = .23, $p = .793$, $\eta^2 = .02$. By looking at the data of Table 1 (right panel) it is evident that subjects of the control group collected relatively equal points across the three 60-trial phases.

Table 1

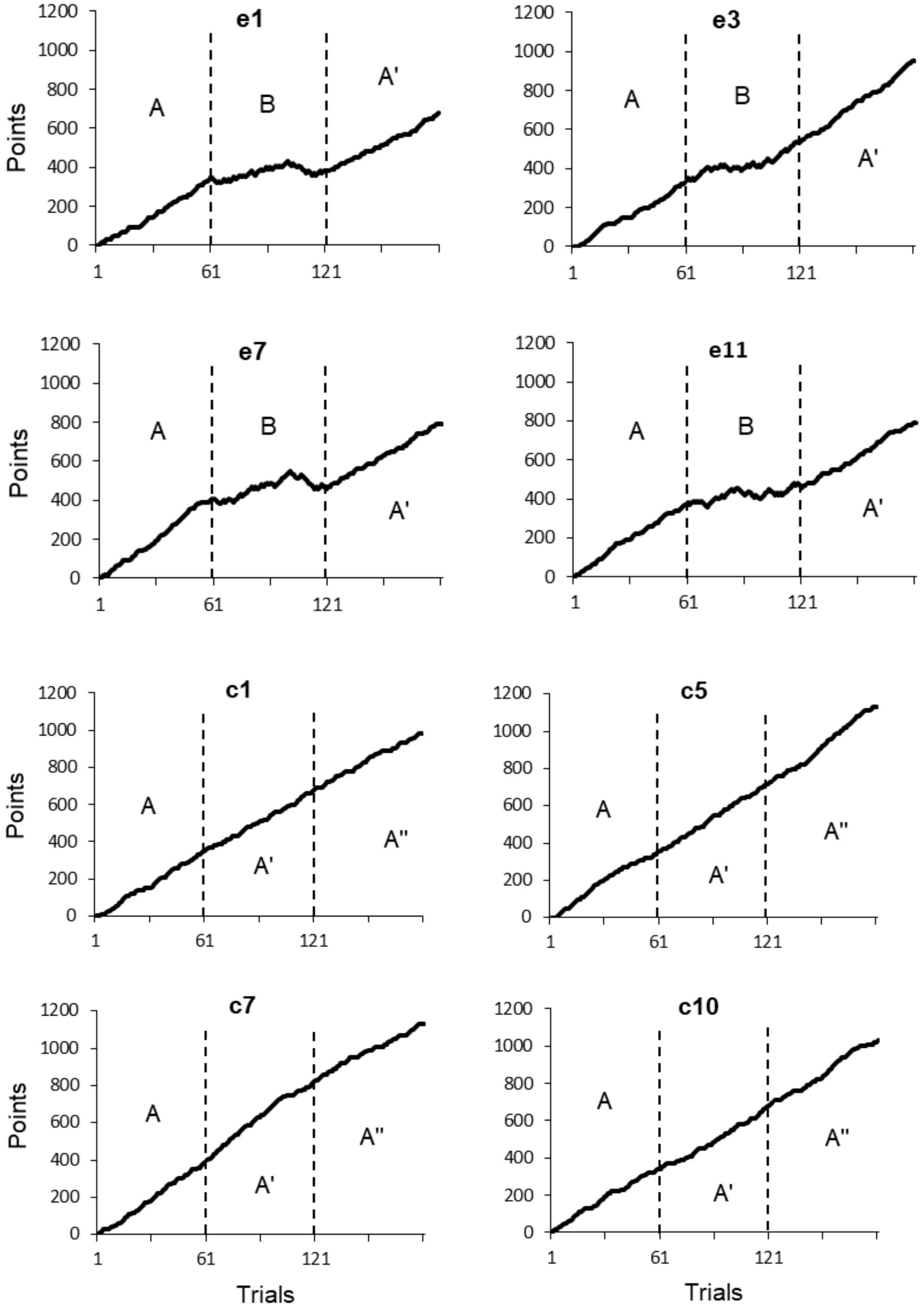
Points earned by each subject across the three phases for experimental and control group in Experiment 1

Experimental Group (ABA'); *N* = 11				Control Group (AAA); *N* = 11			
N.	Phase 1	Phase 2	Phase 3	N.	Phase 1	Phase 2	Phase 3
e1	340	40	300	c1	350	330	310
e2	270	80	290	c2	310	320	290
e3	350	200	420	c3	310	400	430
e4	390	260	350	c4	360	390	380
e5	310	280	330	c5	350	370	410
e6	250	100	380	c6	330	280	330
e7	410	60	320	c7	400	430	300
e8	390	220	430	c8	350	280	350
e9	360	20	350	c9	410	360	310
e10	350	60	340	c10	340	340	350
e11	380	80	330	c11	220	380	380
M	**345.5**	**127.3**	**349.1**	***M***	**339.1**	**352.7**	**349.1**
SE	**15.3**	**28.3**	**13.5**	***SE***	**15.2**	**14.5**	**14.0**

The four upper panels of Figure 3 depict the point earnings cumulatively across the three phases indicatively for four subjects (e1, e3, e7 and e11) and the four lower panels show the same data for four subjects of the control group (c1, c5, c7 and c10). As is illustrated by each diagram separately, in the point-loss phase (upper panels; trials 61-120), there is a reduction in the rate of earning points which is then restored in the third phase (upper panels; trials 121-180). This slowdown is absent in the respective trials of the control group data (lower panels; trials 61-120).

Figure 3

Points earned by certain subjects across phases in Experiment 1



Note. Points earned by eight subjects (vertical axis) across phases (horizontal axis) in Experiment 1. Each graph shows data for one subject across the three conditions. Four upper panels depict four subjects of the experimental group, whereas four lower panels depict four subjects of the control group. Phase 1 included trials 1-60, phase 2 trials 61-120 and phase 3 trials 121-180.

Before examining the variability data, possible order effects should be discussed. In free operant patterning tasks, human subjects (as well as non-human) tend to produce certain stereotypic patterns for two reasons: firstly, due to the absence of reinforcement criteria, free operant schedules favor repeated responses. Secondly, human subjects have their own reinforcement history prior to their visit in the experimental laboratory, which may bias them to respond in certain ways. For example, in a pilot experiment of the current study, patterns were produced by moving the cursor to the four corners of the same context (not by eye movements). In that context, it was observed that the vast majority of the subjects exhibited high stereotypic patterns starting from the upper left black dot and then to the upper right, lower left and lower right, forming a conceivable square. This order effect was unavoidably expected due to the participants' reading/writing history (all subjects were Greek speakers and Greek is read from right to left) in conjunction with their previous interaction with computers. This was the main reason that eye movement was chosen as the kinetic response of pattern production. Of course, an order effect was also expected for the eye-patterning task (note that, cursor moving is also visually guided) but because the stereotypic responding depends primarily by the hand-kinetic history of reinforcement it was hypothesized that visual-motor patterning would be less stereotyped than hand-movement patterning (that was the case as shown in a pilot study).

Specifically, in the baseline phase, subjects of the experimental group produced *M* = 45.3 patterns starting from the upper left corner (*SE* = 5.0) and subjects of the control group produced *M* = 45.6 patterns starting from the upper left corner (*SE* = 4.6). Wilcoxon signed-rank tests (parametric assumptions were not met) showed that subjects produced significantly more patterns starting from the upper left corner (*Mdn* = 51.0, *IQR* = 13.0) than from all the other corners (*Mdn* = 9.0, *IQR* = 13.0), *Z* = -2.091, *p* = .036, indicating a medium to large effect size (*r* = .45). Similarly, in the baseline phase of the control group, subjects emitted a higher number of patterns starting from the upper left corner corner (*Mdn* = 51.0, *IQR* = 9.0) compared to all other patterns that could be produced (*Mdn* = 9.0, *IQR* = 20.0), *Z* = -2.402, *p* = .016, representing a large effect size (*r* = .51).

Before proceeding to the analysis of the stereotypy/variability measurements it was necessary to ensure that these levels were relatively independent of the accuracy of visual search. Thus, in the first phase, Spearman's rank-order correlation was used to assess the relationship between the four main measurements of stereotypy and subjects' detection accuracy in "visible white dot" trials. As it is depicted in Table 2, no significant correlations were observed between the subjects' accuracy in the search task and the four measures of stereotypy. Therefore, levels of visual motor patterning in the first-link task cannot be attributed to the accuracy performance in the second-link task.

Table 2

Spearman Rank-Order Correlations between stereotypy levels and accuracy in the first phase of each group in Experiment 1

Group		Sum of different patterns	Relative frequency of the most prevalent pattern	Relative frequency of the two most prevalent patterns	U-Value
Experimental Group (ABA')	Accuracy	-.34	.51	.29	-.30
Control Group (AAA)	Accuracy	.22	-.3	-.27	.27

Note. $N = 11$ for each group

All p values are > .11.

Table 3 shows the sum of patterns and the relative frequency of the “most prevalent” and “two most prevalent” patterns emitted by each individual of the two groups across the three phases.

Table 3

Topographical stereotypy data for each subject across the three phases for the experimental and control groups in Experiment 1

Experimental Group (ABA'); N = 11

	Sum Diff. Patt.			Most Prev. Patt. Freq.			Two Most Prev. Patt. Freq.		
N.	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
e1	9	7	10	56.7%	83.3%	73.3%	78.3%	88.3%	80.0%
e2	15	17	19	23.3%	15.0%	16.7%	45.0%	28.3%	26.7%
e3	7	9	11	61.7%	61.7%	63.3%	75.0%	78.3%	70.0%
e4	5	2	2	91.7%	98.3%	90.0%	95.0%	100.0%	100.0%
e5	12	9	8	21.7%	48.3%	45.0%	35.0%	66.7%	70.0%
e6	12	3	3	68.3%	98.3%	93.3%	78.3%	100.0%	98.3%
e7	12	10	13	43.3%	68.3%	63.3%	68.3%	83.3%	70.0%
e8	17	17	18	23.3%	38.3%	20.0%	28.3%	45.0%	26.7%
e9	6	3	8	55.0%	96.7%	75.0%	91.7%	98.3%	81.7%
e10	2	2	2	83.3%	98.3%	98.3%	100.0%	100.0%	100.0%
e11	5	3	6	90.0%	93.3%	90.0%	95.0%	98.3%	93.3%
M	**9.3**	**7.5**	**9.1**	**56.2%**	**72.7%**	**66.2%**	**71.8%**	**80.6%**	**74.2%**
SE	**1.4**	**1.7**	**1.8**	**7.9%**	**8.7%**	**8.6%**	**7.6%**	**7.4%**	**7.9%**

Control Group (AAA); N = 11

	Sum Diff. Patt.			Most Prev. Patt. Freq.			Two Most Prev. Patt. Freq.		
N.	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
c1	11	7	7	31.7%	45.0%	63.3%	56.7%	76.7%	76.7%
c2	13	17	14	21.7%	21.7%	26.7%	41.7%	35.0%	38.3%
c3	5	6	7	85.0%	86.7%	71.7%	90.0%	93.3%	90.0%
c4	15	16	18	16.7%	16.7%	13.3%	26.7%	26.7%	25.0%
c5	4	4	3	95.0%	81.7%	80.0%	96.7%	96.7%	98.3%
c6	8	9	7	43.3%	51.7%	40.0%	70.0%	75.0%	78.3%
c7	20	18	19	18.3%	11.7%	20.0%	28.3%	23.3%	36.7%
c8	13	10	5	31.7%	50.0%	43.3%	55.0%	68.3%	70.0%
c9	3	1	1	96.7%	100.0%	100.0%	98.3%	100.0%	100.0%
c10	12	9	9	45.0%	30.0%	43.3%	70.0%	51.7%	60.0%
c11	4	5	4	95.0%	88.3%	88.3%	96.7%	93.3%	93.3%
M	**9.8**	**9.3**	**8.5**	**52.7%**	**53.0%**	**53.6%**	**66.4%**	**67.3%**	**69.7%**
SE	**1.6**	**1.7**	**1.8**	**10.0%**	**9.5%**	**8.7%**	**8.1%**	**8.7%**	**8.0%**

Note. The topographical stereotypy data for each subject across the three phases for the experimental (upper panels) and control group (lower panels) in Experiment 1. The leftmost panels show the raw sums of topographically different fixation patterns; the central panels show the relative frequency data for the most prevalent pattern in each phase; and the right side panels show the sums of the two most prevalent patterns relative to total patterns in each phase.

By inspecting the absolute frequency of the distinct patterns produced in the baseline phase (Table 3, first column), it is evident that there is quite a large inter-subject variance, ranging between two to 15 different patterns in the experimental group and three to 20 in the control group. The high inter-subject variance is also apparent in the other two main measures of visual-motor patterning, also depicted in Table 3. Specifically, the relative frequency of production of the most prevalent pattern in the first phase (Table 3, second column) ranged from 21.7% to 91.7% for the experimental group and 16.7% to 96.7% for the control group, whereas the relative frequency of production of the two most prevalent patterns (Table 3, third column) ranged from 28.3% to 100% for the experimental group and 26.7% to 98.3% for the control group.

It should be noted here that although the sum of distinct patterns and the relative frequency of the most and two most prevalent patterns emitted, varied significantly among subjects, relatively high and systematic stereotypic responding was already observed for the majority of the individuals from the first phase. In particular, seven subjects of the experimental group and four of the control group tended to produce the same topographical pattern in at least 50% of the trials and 8 out of 11 subjects in each group tended to produce the same two patterns in at least 50% of the trials. Furthermore, some of them (e.g., e4, e11, e5, e9 and others) exhibited extremely high stereotypic levels in both relative frequencies measures by producing the same pattern and the same two patterns respectively in at least nine out of 10 trials. Note also, that the percentage of the trials on which one of the two most prevalent patterns was emitted, approached approximately 80% (see black line in lower left panel of Figure 5), indicating a limited potential for observing increases in stereotypy under punishment conditions. Possible experimental limitations of this responding pattern (e.g., ceiling effect) will be later discussed and relevant solutions will also be proposed and implemented in the second experiment.

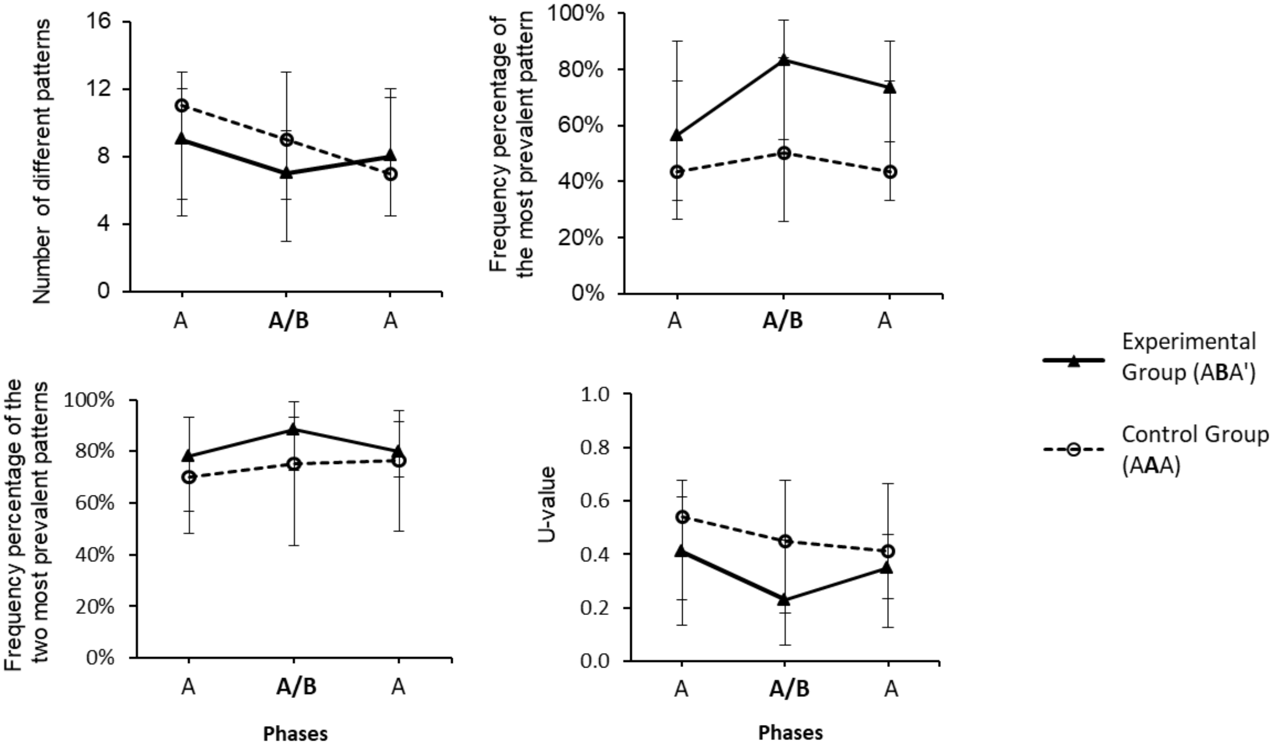
In any case, stereotypy levels in visual-motor patterning in phase 1 were comparably distributed across control and experimental groups. In the second phase, where the control group was exposed to the same reinforcing contingencies for both correct and wrong detections, no systematic and homogeneous changes in gross eye movement-patterning were observed in the first-link task: regarding the relative frequency of the most prevalent pattern, five subjects exhibited higher levels of stereotypy in the second phase compared to the first phase (c1, c3, c6, c8, c9), four subjects exhibited lower levels of stereotypy (c5, c7, c10, c11) and two subjects exhibited stable stereotypy levels (c2, c4). Regarding the relative frequency of the two most prevalent patterns, five subjects exhibited higher levels of stereotypy in the second compared to the first phase (c1, c3, c6, c8, c9), four subjects (c2, c7, c10, c11) exhibited lower levels of stereotypy and two subjects exhibited the same stereotypy levels (c4, c5). By looking in the individual data, it is obvious enough that there is absence of a homogeneous trend in stereotypic/variable responding in the control group.

Statistical comparisons were performed for all four stereotypy measurements and no systematic differences were identified. A Friedman test (normality assumptions were not met) showed that there was no significant effect of the phase series (1^{st}, 2^{nd} and 3^{rd}) on stereotypy levels, for all four stereotypy measures and specifically for the sum of different patterns emitted, $\chi2(2) = 1.43$, $p = .488$, $W = .065$, for the most prevalent pattern, $\chi2(2) = .20$, $p = .905$, $W = .01$, for the two most-prevalent patterns, $\chi2(2) = 1.42$, $p = .491$, $W = .06$ and for the U-value, $\chi2(2) = .65$, $p = .723$, $W = .03$.

In contrast to the control group, subjects of the experimental group, which were exposed to punishment contingencies for detection errors in the second phase (point-loss, color change of the point counter and production of "gaming-failure" sound), tended to emit higher levels of stereotypy in this threatening condition. The average data from the four measures of topographical stereotypy of both groups are depicted graphically in Figure 4, together with the corresponding errors of measurement (interquartile range).

Figure 4

Average levels of topographical stereotypy in patterning of serial fixation for each group in Experiment 1



Note. Levels of topographical stereotypy in patterning of serial fixation for the "point-loss" (triangles) and "no-point-loss" groups (circles) in Experiment 1; phases were identical for both groups except in the second phase where in the point-loss group, actual or perceived errors in the search response were punished with point loss (manipulation phase). The top left panel depicts the raw quantity of topographically distinct patterns observed in each 60-trial phase; the tor right panel depicts, for each phase, the mean percentage of the 60 trials in which the most prevalent pattern was emitted; the lower left panel depicts the mean percentage of total sequences in which either of the two most prevalent fixation patterns was emitted in each phase; the lower right depicts the mean U-value across phases. Medians are plotted and error bars represent interquartile ranges.

A Friedman test (normality assumptions were not met) demonstrated that there was a significant effect of the condition type on stereotypy levels, when assessed by the sum of different patterns produced, $\chi2(2) = .05$, $p = .015$, $W = .27$, representing a relatively moderate effect size. Statistically significant effect was also observed on both the frequency of the most prevalent pattern, $\chi2(2) = 8.39$, $p = .015$, $W = .38$ and the two most prevalent patterns, $\chi2(2) = 8.66$, $p = .013$, $W = .39$, as well as on the U-value, $\chi2(2) = 9.56$, $p = .008$, $W = .43$, representing medium effect sizes.

Regarding the comparison between Phase 1 (absence of programmed punishment contingency) and Phase 2 (point-loss punishment contingency), nine out of 11 subjects responded more stereotypically in the second phase compared to the first phase (e1, e4, e5, e6, e7, e8, e9, e10, e11) when the relative frequency of the most prevalent pattern was measured and again nine out of 11 subjects (e1, e3, e4, e5, e6, e7, e8, e9, e11) responded more stereotypically when the relative frequency of the two most prevalent patterns was taken into account. It is worth mentioning here that, regarding the relative frequency of the two most prevalent patterns, two subjects (e3 and e6) produced only two patterns throughout the point-loss conditions in 100% of the trials (i.e., 60 trials) and two other subjects (e9 and e11) produced only two patterns in 98.3%

of the trials (i.e., 59 trials). Plus, subject e10 repeatedly produced only one pattern throughout the experimental procedure (i.e., in 180 trials).

Post hoc Wilcoxon signed-rank tests using a Bonferroni-adjusted alpha level ($\alpha = .016$) demonstrated that in the experimental group, the relative frequency of the most prevalent pattern was significantly higher in the second phase (*Mdn* = 83.3%, *IQR* = 42.5%) compared to the first phase (*Mdn* = 56.6%, *IQR* = 42.5%, *Z* = -2.50, *p* = .012), indicating a large effect size (*r* = .53). The observed statistical difference in stereotypy levels between Phase 1 and 2 was less reliable when assessed by the sum of differences patterns emitted, (*Mdn* = 9, *IQR* = 6.5 in Phase 1 and *Mdn* = 7, *IQR* = 7 in Phase 2, *Z* = -2.00, *p* = .046), representing a medium effect size (*r* = .43), the relative frequency of the two most prevalent patterns (*Mdn* = 78.33%, *IQR* = 36.7% in Phase 1 and *Mdn* = 88.3%, *IQR* = 26.7% in Phase 2, *Z* = -2.04, *p* = .04), representing a large effect size (*r* = .55) or by the U-value (*Mdn* = .41, *IQR* = .39 in Phase 1 and *Mdn* = .23, *IQR* = .50 in Phase 2, *Z* = -2.29, *p* = .022), representing a medium effect size (*r* = .49).

After the second point-loss contingency phase, subjects of the experimental group were exposed to the initial baseline schedule of Phase 1, where errors in the second-link search task were not punished. By inspecting Table 3, it is notable that for eight of the nine subjects whose patterning tendency in the first-link task became more stereotyped, as measured by the relative frequency of the most prevalent pattern (e1, e4, e5, e6, e7, e8, e9 and e11), it became more variable again when punishment contingency was removed in the reversal phase. A similar pattern was observed when serial fixation patterning was assessed by the relative frequency of the two most prevalent patterns, where for seven of the nine subjects (e1, e3, e5, e7, e8, e9, e11) whose fixation patterns became more stereotyped in the ‘threatening’ Phase 2 conditions, visual-motor patterning eventually became more variable when punishment ceased in the third phase. This trend was absent in the control group data, where three out of five subjects that exhibited higher levels of stereotypy in the second phase produced more variable fixation patterns in the third phase when assessed by the relative frequency of the most prevalent pattern (c3, c6 and c8) and one subject out of five when assessed by the relative frequency of the two most prevalent patterns (c3).

Although baseline operant levels of variability in serial fixation patterning were fully recovered only (even increased more in some cases) in two subjects (e4 and e8) when assessed by the relative frequency of the most prevalent pattern and in five subjects (e3, e7 e8, e9, e11) when assessed by the relative frequency of the two most prevalent patterns, a statistically significant difference between stereotypy levels of Phase 2 and Phase 3 was found using Post hoc Wilcoxon signed-rank tests (adjusted level, $\alpha = .016$). Specifically, after the cessation of point-loss contingency in Phase 3, subjects tend to emit less stereotyped fixation patterns, whether measured by the relative frequency of the most prevalent pattern (*Mdn* = 83.3%, *IQR* = 42.5% Phase 2 and *Mdn* = 73.3%, *IQR* = 35.8% in Phase 3, *Z* = -2.50, *p* = .012, *r* = .53), or the U-values (*Mdn* = .23, *IQR* = .40 in Phase 2 and *Mdn* =.35, *IQR* = .35 in Phase 3, *Z* = -2.61, *p* = .009), representing a large effect size (*r* = .56). This difference was statistically less reliable when assessed by the sum of different patterns produced (*Mdn* = 7, *IQR* = 7 in Phase 2 and *Mdn* = 8, *IQR* = 7.5 in Phase 3, *Z* = -2.33, *p* = .020, *r* = .50) or the two most prevalent patterns (*Mdn* = 88.3%, *IQR* = 26.7% in Phase 2 and *Mdn* = 80%, *IQR* = 25.8% in Phase 3, *Z* = -2.31, *p* = .021, *r* = .49) indicating, however, large effect sizes in both cases.

Finally, in order to exclude the possibility that possible repetitive patterns that were emitted in the point-loss phase have been differentially reinforced independently of the experimental contingency programming, total errors were calculated (both actual and perceived) and compared across the three phases for the experimental group. Table 4 shows the percentage of actual and perceived errors separately.

Table 4

Percentage of actual and perceived search errors of each subject across the three phases for experimental and control groups in Experiment 1

Experimental Group (ABA'); *N* = 11

	Actual (visible white dot) errors			Perceived (no white dot) errors		
N.	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
e1	3.4%	3.4%	0.0%	80.6%	87.1%	81.1%
e2	25.0%	8.0%	7.1%	75.0%	68.6%	90.6%
e3	0.0%	0.0%	0.0%	71.4%	71.4%	66.7%
e4	0.0%	0.0%	0.0%	67.7%	53.1%	80.6%
e5	25.7%	3.2%	13.3%	80.0%	51.7%	76.7%
e6	12.5%	6.7%	0.0%	88.9%	76.7%	73.3%
e7	12.9%	15.4%	14.7%	51.7%	67.6%	88.5%
e8	0.0%	0.0%	0.0%	87.5%	79.2%	68.0%
e9	12.1%	11.1%	10.0%	74.1%	69.6%	76.7%
e10	9.4%	4.0%	0.0%	78.6%	74.3%	78.8%
e11	10.3%	3.8%	6.7%	85.7%	73.5%	83.3%
M	**10.1%**	**5.1%**	**4.7%**	**76.5%**	**70.3%**	**78.6%**
SD	**9.1%**	**4.9%**	**5.9%**	**10.6%**	**10.4%**	**7.5%**

Control Group (AAA); *N* = 11

	Actual (visible white dot) errors			Perceived (no white dot) errors		
N.	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
c1	0.0%	3.4%	0.0%	78.1%	83.9%	80.6%
c2	10.0%	4.0%	8.3%	80.0%	68.0%	73.1%
c3	20.0%	3.4%	0.0%	68.6%	61.3%	58.6%
c4	9.1%	11.1%	0.0%	77.8%	70.8%	73.3%
c5	12.1%	0.0%	3.0%	77.8%	65.7%	66.7%
c6	7.1%	21.4%	25.0%	78.1%	81.3%	79.2%
c7	3.2%	0.0%	0.0%	65.5%	56.7%	75.0%
c8	8.6%	4.2%	0.0%	88.0%	86.1%	80.6%
c9	0.0%	0.0%	14.8%	65.5%	80.0%	75.8%
c10	11.1%	9.7%	10.3%	69.7%	79.3%	71.0%
c11	32.0%	8.6%	7.9%	85.7%	76.0%	86.4%
M	**10.3%**	**6.0%**	**6.3%**	**75.9%**	**73.5%**	**74.6%**
SD	**9.2%**	**6.4%**	**8.1%**	**7.6%**	**9.7%**	**7.5%**

Note. Task performance of each subject, as assessed by the errors made when the white dot in the second-link search task was visible (actual errors; first column) and not visible (perceived errors; second column).

As it is evident, differences in the mean total number of errors (M_1 = 42.5%, SE = 2.5% in the baseline phase, M_2 = 38.5 %, SE = 2.2% in the manipulation phase and M_3 = 42.0%, SE = 2.3% in the reversal phase) were minimal and statistically non-significant, $F(2, 20) = 1.19$, $p = .323$, $\eta^2 = .06$.

Finally, during the post-experimental interviews, participants tended to discuss, usually spontaneously, their difficulty in detecting the white dot in some trials. However, none of them claimed, spontaneously or when directly asked, that the white dot did not actually appear in certain cases. Furthermore, all of the subjects that were assigned to the experimental group reported (either spontaneously or when asked) the transition from the baseline no-point-loss condition to the punishment-based point-loss condition and its contingency reversal in the third phase.

Experiment 2

Method

Subjects

Sixteen subjects were voluntarily recruited for the second study. Twelve of them were first and second-year undergraduate psychology students without any previous knowledge of the research topic. They ranged in age from 19 to 28 years (M = 21.7), and 12 were self-identified as females and four as males. All of them had normal or corrected vision (with eyeglasses or contact lenses). As in the first experiment, subjects signed an informed consent form (see Appendix A) prior to the experimental procedure, and after its end, they were similarly fully debriefed.

Equipment, apparatus and procedure

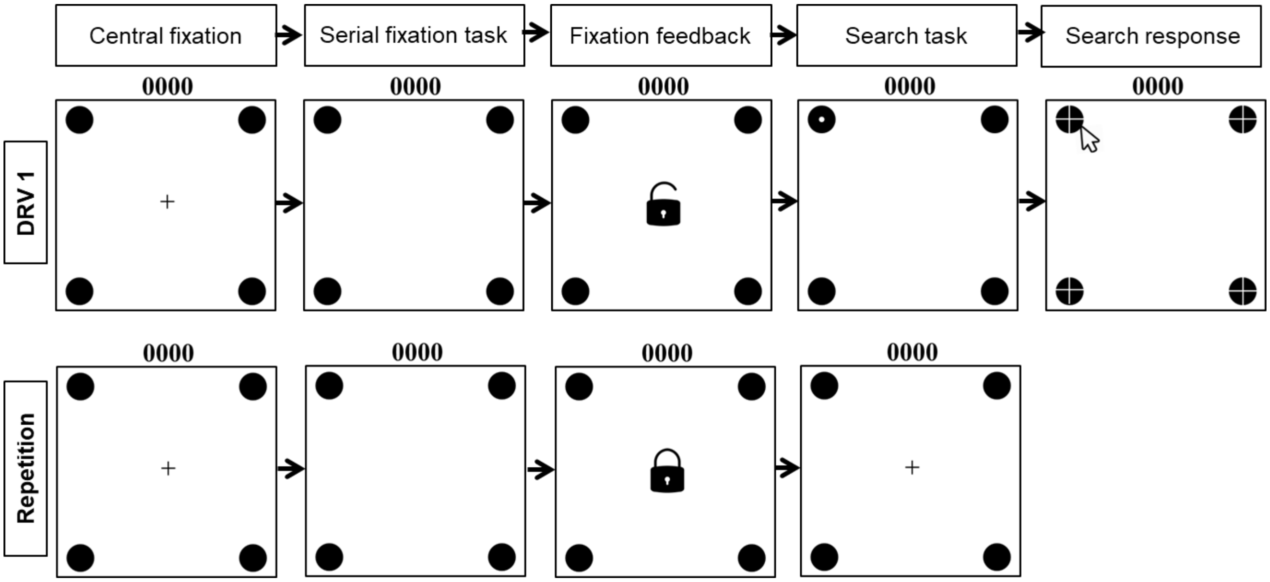
The equipment, apparatus and procedure were the same as in Experiment 1.

Task

The task of the second experiment was almost identical to the first task except for one crucial difference: throughout the experiment, during the first-link visual-motor patterning task, subjects' behavior was reinforced with the open padlock only if the pattern produced in each trial differed from the one produced in the previous trial (i.e., lag 1 or differential reinforcement of variability schedule 1 or DRV schedule). Conversely, if the emitted pattern was the same with the previous, a locked padlock appeared and a new trial began. Figure 5 depicts these two scenarios.

Figure 5

Illustration of the task components in Experiment 2



Note. Task components of Experiment 2 were the same as in Experiment 1 except for the criteria to proceed to the search task: in order to produce the open padlock, subjects had to emit a fixation pattern in the serial fixation task that was different from the pattern emitted in the previous trial (e.g., lag 1). If subjects repeated the same visual-motor pattern, a locked padlock appeared (1.5 seconds with a “lock” sound) and a new trial ensued.

All other parameters of the task and experimental design were the same as in the first experiment. Specifically, subjects were assigned randomly in one out of two groups; subjects of the first group performed the above-described task in an ABA’ design (as in the first experiment) where the reinforcement, point-gaining contingencies were the same throughout the experiment, but the punishment, point-loss contingencies differed across the phases. Specifically, in the first (baseline) and third phase (reversal), false detections were not punished with point deduction, but in the second phase they were punished with loss of 10 points, a relevant gaming-failure and a change in the color of the point counter from white to red. Subjects of the second group (control group; AAA design) performed the same task but without being exposed to the point-loss punishing conditions in the second phase. The same four measures of stereotypy/variability levels were again employed with the addition of the number of failures to vary across phases, where higher values of failure indicate lower levels of variability (and worse performance in the first-link task overall).

Statistical analysis

The same software tools as in the first experiment were used to analyze the data of the second experiment statistically.

Results

As in Experiment 1, the total trials of the control groups were divided into three dummy phases of 60 trials each. Subject c6 performed 150 trials instead of 180 due to a programming error (50 trials in each phase). Participants’ general performance was then assessed in order to identify responding patterns that may imply a lack of engagement or vision deficit. All subjects had stable and adequate performance throughout the experimental task as measured by the percentage of correct responses in the trials where the white dot was actually visible For the ABA' group, the mean percentage of correct detections in the "visible white dot" trials was M_1 = 90.6% (*SE* = 3.6%) in Phase 1, M_2 = 89.9% (*SE* = 3.2%) in Phase 2 and M_3 = 89.5% (*SE* = 4.9%) in Phase 3. Similar detection performance was observed in the control group, too, where the mean percentage of correct choices in the same type of trials was M_1 = 91.5% (*SE* = 3.0%) in Phase 1, M_2 = 87.2% (*SE* = 3.4%) in Phase 2 and M_3 = 92.9% (*SE* = 2.8%) in Phase 3. Further assessment of individual data did not reveal any atypically low accuracy performance, as measured by the percentage of correct responses in the "visible white dot" trials (range 73-100% for the experimental group and 75-100% for the control group) or any pattern of a high-order stereotypy in any of the subjects.

The next step was to ensure that points earning momentum was suppressed for subjects of the experimental group who were exposed to point-loss contingencies in Phase 2 but not for subjects of the control group. Subjects of the experimental group gathered on average M_1 = 241.3 points (*SE* = 17.5) in Phase 1, M_2 = 68.8 points (*SE* = 41.7) in Phase 2 and M_3 = 282.5 (*SE* = 18.7) in Phase 3. In contrast, subjects of the control group gained relatively the same amount of points in all three phases and specifically, M_1 = 268.8 (*SE* = 14.2) in Phase 1, M_2 = 256.3 (*SE* = 17.4) in Phase 2 and M_3 = 277.5 (*SE* = 14.6) in Phase 3. Table 5 shows the sum of points earned by the subjects of each group across the three phases.

Table 5

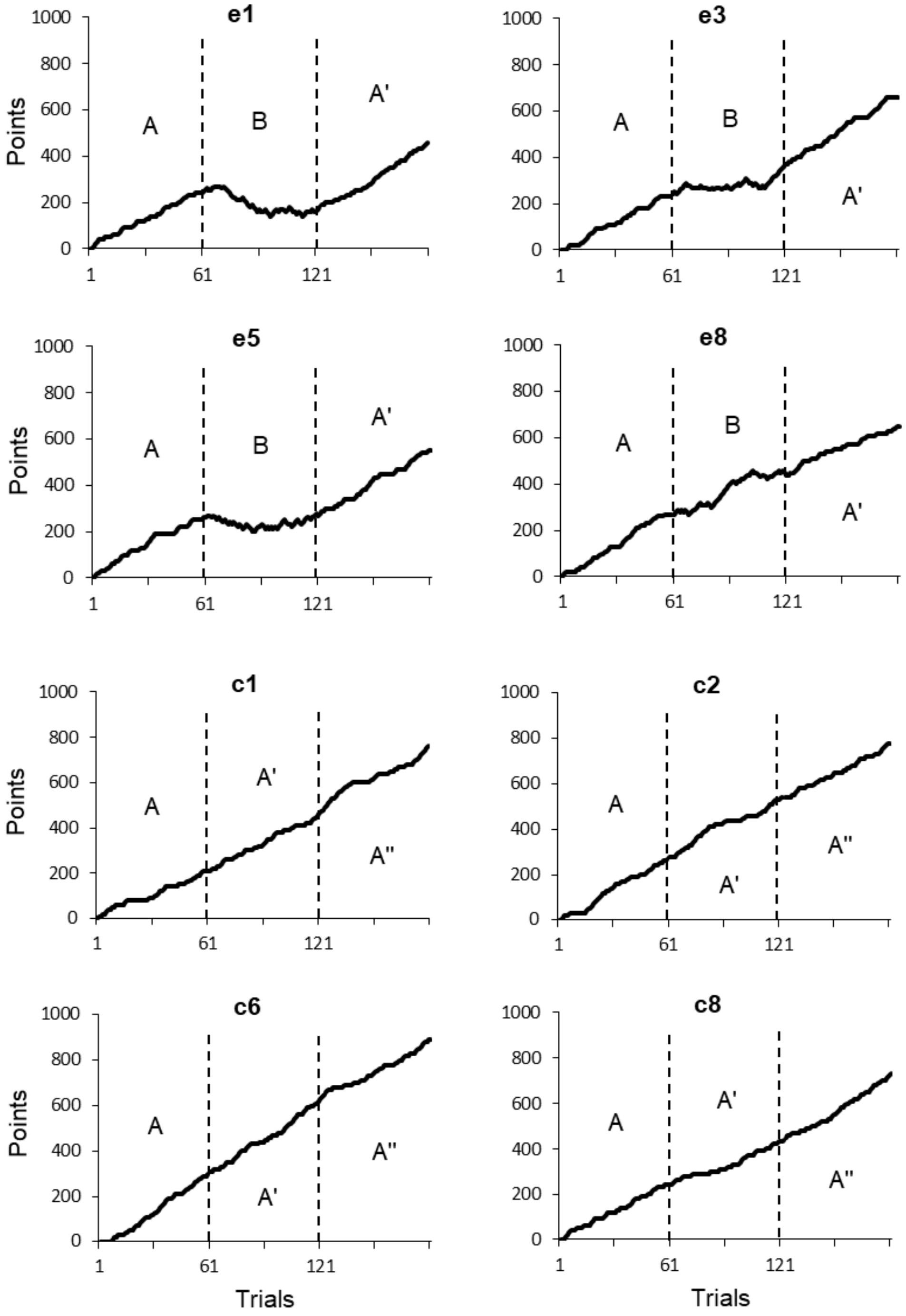
Points earned by each subject across the three phases when white dot was visible for the experimental and control groups in Experiment 2

Experimental Group (ABA'); *N* = 8				Control Group (AAA); *N* = 8			
N.	Phase 1	Phase 2	Phase 3	N.	Phase 1	Phase 2	Phase 3
e1	250	-80	290	c1	220	240	310
e2	220	190	390	c2	270	260	250
e3	240	130	300	c3	340	300	280
e4	280	110	260	c4	240	310	220
e5	260	10	280	c5	240	210	230
e6	130	-120	270	c6	310	320	300
e7	270	130	270	c7	280	220	340
e8	280	180	200	c8	250	190	290
M	**241.3**	**68.8**	**282.5**	***M***	**268.8**	**256.3**	**277.5**
SE	**17.5**	**41.7**	**18.7**	***SE***	**14.2**	**17.4**	**14.6**

It is clear that the point-loss manipulation was introduced successfully in the second phase of the experimental group because subjects that were exposed to this condition collected significantly fewer points in Phase 2 compared to Phases 1 and 3, whereas subjects of the control group gathered points relatively with the same rate across phases. The decreasing in the point-earnings rate is visually depicted in the four upper panels of Figure 6. It should be noted here that subjects e1 and e6 were the only ones whose points were decreased (-80 and -120 respectively) in the point-loss phase because, in the “non-visible white dot” trials of Phase 2, they made only fewer correct guesses than the 25% average.

Figure 6

Points earned by certain subjects across phases in Experiment 2



Note. Points earned by eight subjects (vertical axis) across phases (horizontal axis) in Experiment 2. Each graph shows data for one subject across the three conditions. Four upper panels depict four subjects of the experimental group, whereas four lower panels depict four subjects of the control group. Phase 1 included trials 1-60, phase 2 trials 61-120 and phase 3 trials 121-180.

For the reasons discussed in the relevant section of the previous experiment, an order effect was again expected in the baseline phase of the second experiment for both groups. For the experimental group, the mean order effect was *M* = 25.6 (*SE* = 5.2) and for the control group, the respective value was *M* = 35.3 (*SE* = 5.2). Although this difference does not affect the conceptual analysis and interpretation of the results (see Discussion section), it should be taken into account because it stresses the importance of a different type of stereotypic responding, which is based on prior reinforcement and punishment history of each subject as well. In any case, due to the implementation of the DRV schedule, this order effect was not statistically reliable. Specifically, a Wilcoxon signed-rank test demonstrated that in the baseline phase, subjects of the experimental group did not produce relatively the same patterns starting from the upper left corner (*Mdn* = 28.0, *IQR* = 20.5) compared to all other patterns (*Mdn* = 32.0, *IQR* = 20.5), *Z* = -.70, *p* = .484, representing a small effect size (*r* = .15). Similarly, subjects of the control group, did not produce significantly more patterns starting from the upper left corner (*Mdn* = 38.0, *IQR* = 19.8) that all other patterns (*Mdn* = 22.0, *IQR* = 19.8), *Z* = -1.05, *p* = .293, indicating, again, a small effect size (*r* = .22).

A Spearman’s rank-order correlation was then again performed in order to test if the inter-subject variance in levels of stereotypy patterning was unrelated to the accuracy of visual search in the first phase of the experiment. As it is demonstrated in Table 6, there were no significant correlations between the four measures of visual-motor patterning stereotypy in the first-link task and detection accuracy in the second-link task.

Table 6

Spearman Rank-Order Correlations between stereotypy levels and accuracy in the first phase of each group in Experiment 2

Group		Sum of different patterns	Relative frequency of the most prevalent pattern	Relative frequency of the two most prevalent patterns	U-Value
Experimental Group (ABA')	Accuracy	-.18	.15	.36	.05
Control Group (AAA)	Accuracy	-.19	-.29	-.03	-.06

Note. N = 11 for both groups

All *p* values are > .38.

Before proceeding to the analysis of the relevant stereotypy/variability levels, the efficiency of the differential reinforcement of variability schedule should be checked. It should be reminded here that the DRV schedule (i.e., lag 1) in the first-link task of the second experiment was introduced in order to test the relation (and possibly the interaction) between stereotypic/variable patterning, the punishment procedure (in a different context) and the reinforcing history of the subject. However, this additional experimental manipulation helped to solve an issue that arose in Experiment 1. As it was mentioned earlier, several subjects of Experiment 1 (e.g., e4, e11, c5, c9, c11) exhibited highly stereotypic responding (relative frequency of the most and two most prevalent patterns was above 90% already by the first phase; see Table 3), which may hindered the potential for the evocative effects of punishment to be observed due to a ceiling effect. Thus, the implementation of the DRV schedule could possibly limit this stereotypic tendency and provide a better insight into the relevant phenomenon.

Table 7 illustrates the mean difference in baseline stereotypy levels between No DRV (ABA' No DRV and AAA No DRV) and DRV conditions (ABA' DRV and AAA DRV), as assessed by the four relevant measures.

Table 7

Stereotypic responding assessment in baseline between No DRV (Exp. 1) and DRV (Exp. 2) first-link tasks

Experiment	Sum of different patterns		Relative frequency of the most prevalent pattern		Relative frequency of the two most prevalent patterns		U-Value	
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
1st (No DRV)	9.5	1.1	54.5%	6.2%	69.1%	5.5%	0.44	0.06
2nd (DRV)	13.3	0.8	28.0%	2.2%	47.4%	3.2%	0.65	0.03

Note. Mean topographical stereotypy data for each experimental group in baseline phase. The first column shows the sum of distinct patterns emitted, the second column shows the relative frequency of the most prevalent pattern, the third column shows the mean frequency of the two most prevalent patterns and the fourth column shows the U-values.

On average, subjects that were exposed to the lag schedule (Experiment 2), exhibited higher levels of topographic variability in all four measurements compared to those that were exposed to free operant conditions (Experiment 1). All of these differences were statistically significant, and specifically, $t(35.8) = -2.75$, $p = .009$, $d = .74$, for the sum of different patterns emitted, $t(26.1) = 3.99$, $p < .001$, $d = .90$, for the relative frequency of the most prevalent pattern, $t(32.5) = 3.43$, $p = .004$, $d = .85$, for the relative frequency of the two most prevalent patterns and $t(28.8) = -3.39$, $p = .002$, $d = .79$, for the U-value. It is evident that the application of the lag 1 schedule was successful in increasing variability levels of visual-motor patterning in Experiment 2. The DRV effect is also conspicuous when inspecting individual stereotypy data in Table 8. None of the subjects produced their most prevalent patterns in more than 48.3% of the trials and only one subject produced his/her two most prevalent patterns in more than 61.7% of trials (c2; 76.7%). Subsequently, no ceiling effect was observed in any of the subjects, not only in Phase 1 but also in Phases 2 and 3.

In contrast with the free operant control conditions of Experiment 1, where visual-motor patterning variance was quiet large already in the first phase of the task (range from two to 15 distinct patterns in the ABA’ group and from three to 20 in the AAA group), subjects of Experiment 2 produced visual-motor patterns with a range from nine to 20 in the ABA’ group and seven to 16 in the AAA group. The decreased inter-subject variance is also well depicted in the reduction of the standard errors of each stereotypy measure in Table 8. This was another substantial effect of the differential reinforcement of variability procedure.

Table 8

Topographical stereotypy data for each subject across the three phases for the experimental and control groups in Experiment 2

Experimental Group (ABA'); *N* = 8

	Sum Diff. Patt.			Most Prev. Patt. Freq.			Two Most Prev. Patt. Freq.		
N.	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
e1	12	11	10	28.3%	31.7%	33.3%	53.3%	50.0%	58.3%
e2	19	17	18	15.0%	11.7%	11.7%	25.0%	21.7%	23.3%
e3	14	11	12	33.3%	28.3%	26.7%	51.7%	55.0%	50.0%
e4	20	22	21	16.7%	11.7%	15.0%	31.7%	23.3%	30.0%
e5	15	15	13	23.3%	23.3%	20.0%	43.3%	33.3%	36.7%
e6	12	14	9	22.0%	14.0%	18.0%	36.0%	26.0%	10.0%
e7	9	15	9	43.3%	23.3%	31.7%	61.7%	40.0%	51.7%
e8	15	15	15	18.3%	28.3%	21.7%	38.3%	51.7%	40.0%
M	**14.5**	**15.0**	**13.4**	**25.0%**	**21.5%**	**22.3%**	**42.6%**	**37.6%**	**37.5%**
SE	**1.3**	**1.2**	**1.5**	**3.4%**	**2.8%**	**2.7%**	**4.3%**	**4.8%**	**5.7%**

Control Group (AAA); *N* = 8

	Sum Diff. Patt.			Most Prev. Patt. Freq.			Two Most Prev. Patt. Freq.		
N.	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
c1	11	12	14	33.3%	30.0%	25.0%	56.7%	50.0%	18.3%
c2	11	8	7	48.3%	51.7%	48.3%	76.7%	86.7%	88.3%
c3	13	16	14	31.7%	28.3%	21.7%	48.3%	48.3%	40.0%
c4	16	17	15	26.7%	25.0%	23.3%	35.0%	36.7%	35.0%
c5	7	11	15	23.3%	38.3%	16.7%	45.0%	58.3%	30.0%
c6	14	13	17	30.0%	26.7%	18.3%	56.7%	45.0%	48.3%
c7	12	13	10	26.7%	38.3%	40.0%	45.0%	55.0%	60.0%
c8	12	11	10	28.3%	31.7%	33.3%	53.3%	50.0%	58.3%
M	**12.0**	**12.6**	**12.8**	**31.0%**	**33.8%**	**28.3%**	**52.1%**	**53.8%**	**47.3%**
SE	**0.9**	**1.0**	**1.2**	**2.7%**	**3.1%**	**4.0%**	**4.3%**	**5.2%**	**7.7%**

Note. The topographical stereotypy data for each subject across the three phases for the experimental (upper panels) and control group (lower panels) in Experiment 2. The leftmost panels show the raw sums of topographically different fixation patterns; the central panels show the relative frequency data for the most prevalent pattern in each phase; and the right side panels show the sums of the two most prevalent patterns relative to total patterns in each phase.

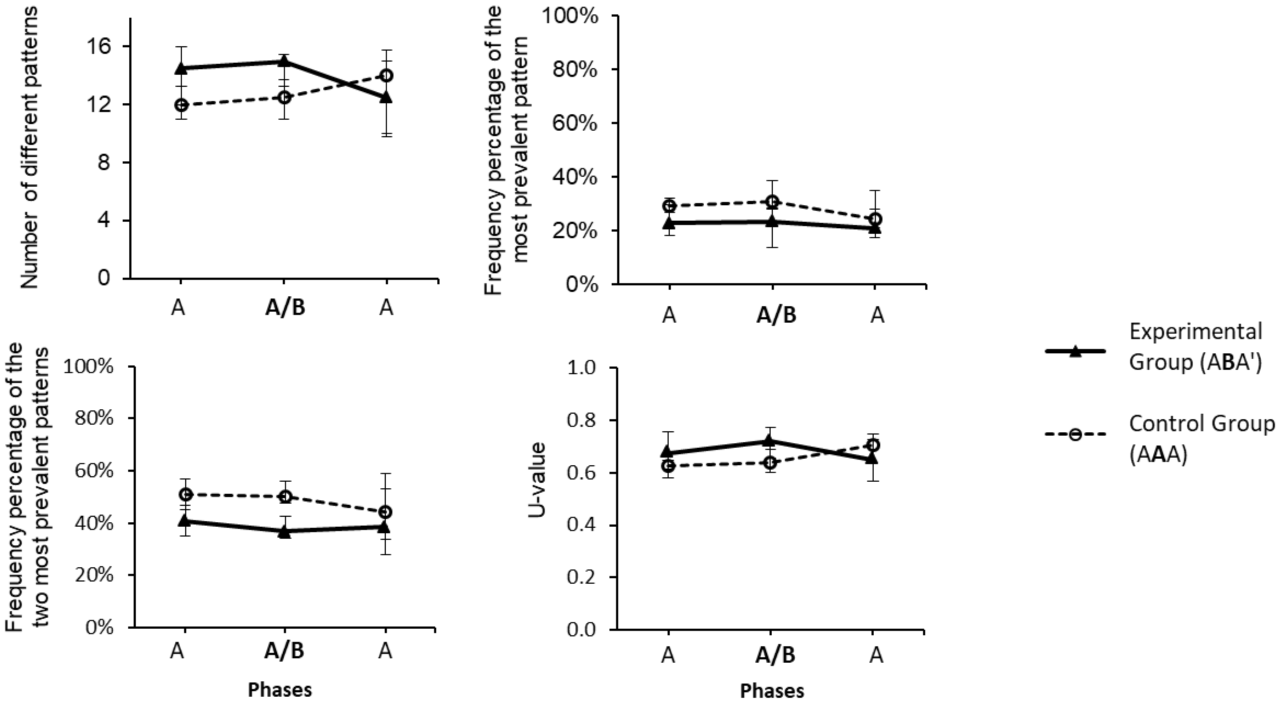
In the second phase, the control group's gross eye movement stereotypy levels were relatively stable on average but not uniform across subjects. Regarding the relative frequency of the most prevalent pattern, half of the subjects exhibited higher levels of variability in the second phase compared with the first phase (c1, c3, c4 and c6) and the other half exhibited lower levels of variability (c2, c5, c7, c8). However, most of these changes were quite slight (approximately 3% in six out of eight subjects). Regarding the relative frequency of the two most prevalent patterns, subjects exhibited similar mixed stereotypic patterning levels. Three of them behaved more variably in Phase 2 compared to Phase 1 (c1, c6, c8), four of them more stereotypically (c2, c4, c5 and c7) and one of them exhibited the same levels of stereotypic responding (c3). In any case, it is impossible to detect a homogeneous trend in the control group.

Statistical analysis confirmed the existence of high individual subject variance in levels of patterning variability in the control group. Due to normality violations, a Friedman test was performed in order to test for an effect of the phase series (1st, 2nd and 3rd; i.e., trials 1-60, 61-120 and 121-180, respectively) on stereotypic responding and yielded non-significant differences: for the sum of distinct patterns produced, $\chi2(2) = .75$, $p = .687$, $W = .05$, for the most prevalent pattern, $\chi2(2) = 2.39$, $p = .303$, $W = .15$, for the two most-prevalent patterns, $\chi2(2) = .07$, $p = .967$, $W = .01$ and for the U-value, $\chi2(2) = 1.00$, $p = .607$, $W = .06$.

The point-loss condition in which subjects of the experimental group were exposed, produced however more systematic behavioral manifestations. Specifically, five out of eight subjects produced more variable visual-motor patterns in the punishment-based context of Phase 2 compared with Phase 1 (e2, e3, e4, e6 and e7), when measured by the relative frequency of the most prevalent pattern, two subjects produced less variable patterns (e1 and e8) and one subject produced the most prevalent pattern with the same frequency (e5). The data were much clearer when stereotypic responding was assessed by the relative frequency of the two most prevalent patterns, where six subjects (e1, e2, e4, e5, e6, and e7) emitted more variable patterns in the second phase (point-loss contingency) in comparison to the first phase whereas two subjects (e3 and e8) emitted less variable patterns. Figure 7 illustrates the mean topographical stereotypy data for each group across the three phases, calculated by the four main stereotypy measures.

Figure 7

Average levels of topographical stereotypy in patterning of serial fixation for each group in Experiment 2



Note. Levels of topographical stereotypy in patterning of serial fixation for the “point-loss” (triangles) and “no-point-loss” groups (circles) in Experiment 2; phases were identical for both groups except in the second phase where in the point-loss group, errors in the search response were punished with point-loss. The top panel depicts the raw quantity of topographically distinct patterns observed in each 60-trial phase; the second panel depicts, for each phase, the mean percentage of the 60 trials in which the most prevalent pattern was emitted; the third panel depicts the mean percentage of total patterns in which either of the two most prevalent fixation patterns was emitted in each phase; the lower panel depicts the mean U-value across phases. Medians are plotted and error bars represent interquartile ranges.

In contrast to the findings of Experiment 1, statistical analysis revealed no significant effect of condition type on visual-motor stereotypic responding in Experiment 2. Specifically, a Friedman test indicated that condition type did not significantly change stereotypy patterning levels when assessed by the sum of different patterns produced, $\chi2(2) = 2.85$, $p = .241$, $W = .18$, by the relative frequency of the most prevalent pattern, $\chi2(2) = 2.47$, $p = .291$, $W = .15$ and two most prevalent patterns, $\chi2(2) = 3.25$, $p = .197$, $W = .20$, as well as by the U-value, $\chi2(2) = .25$, $p = .882$, $W = .02$, representing relatively small effect sizes in all cases.

When the point-loss threatening context was terminated in Phase 3, four out of five subjects that had exhibited higher levels of variability in the punishment condition produced more stereotyped visual-motor patterns when assessed by the relative frequency of the most prevalent pattern (e3, e4, e6 and e7) or the two most prevalent patterns (e1, e2, e4, e5 and e7). This behavioral pattern did not appear in the control group, where none of the subjects that behaved more variably in the second phase produced more stereotypic patterns in the third phase when assessed by the relative frequency of the most prevalent pattern, and two out of three subjects (c6 and c8) behaved more stereotypically when assessed by the relative frequency of the two most prevalent patterns. It is important to note here that, for both groups, the differences in average and especially in individual levels of visual-motor patterning stereotypy were less robust and systematic compared with the first experiment. Analysis and discussion of possible limitations in Experiment 2 will be provided later.

One last measure of stereotypy that was used in the second experiment was the frequency of trials where subjects failed to proceed from the first-link patterning task to the second-link task search task. High failure rates of meeting the criterion of the lag 1 schedule imply that the subject repeatedly produces the same visual-motor patterns over and over again, whereas low failure rates imply increased variability of visual-motor patterning. Table 9 shows individual and mean lag failures across phases.

Table 9

Unsuccessful attempts to fulfill the criterion of DRV in the first-link patterning task across phases for each group

Group							
Experimental Group (ABA'); *N* = 8				Control Group (AAA); *N* = 8			
N.	Phase 1	Phase 2	Phase 3	N.	Phase 1	Phase 2	Phase 3
e1	17	14	14	c1	8	7	6
e2	5	5	2	c2	20	13	16
e3	17	15	12	c3	13	11	12
e4	8	3	3	c4	10	5	7
e5	9	5	12	c5	16	11	6
e6	21	4	11	c6	17	7	1
e7	17	9	12	c7	15	14	13
e8	10	12	14	c8	17	14	14
M	**13.0**	**8.4**	**10.0**	***M***	**14.5**	**10.3**	**9.4**
SE	**2.0**	**1.7**	**1.7**	***SE***	**1.4**	**1.2**	**1.8**

Note. Individual and mean lag failures across phases for the two groups.

Both groups had comparable mean frequencies of lag failures in Phase 1, M_1 = 13 for the experimental and M_1 = 14.5 for the control group, which were then decreased in Phase 2 (point-loss contingency for the experimental group and absence of point-loss contingency for the control group) to M_2 = 8.4 and M_2 = 10.3 respectively, as subjects were undergoing the DRV procedure. Lag failures were further reduced for the control group (M_3 = 9.4) in Phase 3, but this was not the case for the experimental group, where mean lag failures slightly increased after the removal of the punishment-based contingency (M_3 = 10.0). However, statistical analysis did not reveal a significant effect of the condition type on lag failures in the experimental group, $\chi2(2) = 4.621$, $p = .099$, $W = .289$, representing a moderate effect size, whereas the phase series had a statistically significant impact on lag failures in the control group, $\chi2(2) = 12.452$, $p = .002$, $W = .778$, representing a large effect size. Post hoc Wilcoxon signed-rank tests (adjusted level, $\alpha = .016$) showed that subjects of the control group tended to make more lag failures in Phase 1 (*Mdn* = 15.5, *IQR* = 4.8) compared to Phase 2 (*Mdn* = 11.0, *IQR* = 6.3), $Z = 2.875$, $p = .004$, indicating a large effect size ($r = .61$), and compared to Phase 3 (*Mdn* = 8.5, *IQR* = 7.3), $Z = 3.125$, $p = .002$, again indicating a large effect size ($r = .67$). Regarding the same group, no statistically reliable difference was found between Phase 2 and 3 ($Z = .250$, $p = .803$, $r = .05$).

Total and perceived errors were then calculated for the experimental group across phases in order to check whether variable visual-motor responses in the first-link task were somehow reinforced with point-gaining in the second-link task independently of the programmed contingency. Table 10 indicates the percentage of actual and perceived errors.

Table 10

Percentage of actual and perceived search errors of each subject across the three phases for experimental and control groups in Experiment 2

Experimental Group (ABA'); *N* = 8

	Actual (visible white dot) errors			Perceived (no white dot) errors		
N.	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
e1	0.0%	10.5%	4.2%	75.0%	92.6%	72.7%
e2	0.0%	10.7%	10.5%	89.2%	55.6%	75.0%
e3	16.0%	0.0%	3.7%	83.3%	69.6%	85.0%
e4	19.0%	27.0%	42.9%	64.5%	65.0%	65.5%
e5	16.7%	16.7%	4.0%	74.1%	75.9%	81.8%
e6	23.5%	13.0%	13.6%	58.3%	91.3%	52.9%
e7	0.0%	3.4%	0.0%	64.0%	81.8%	77.8%
e8	0.0%	0.0%	5.3%	78.6%	75.0%	88.9%
M	**9.4%**	**10.2%**	**10.5%**	**73.4%**	**75.8%**	**75.0%**
SE	**3.6%**	**3.2%**	**4.9%**	**3.7%**	**4.5%**	**4.1%**

Control Group (AAA); *N* = 8

	Actual (visible white dot) errors			Perceived (no white dot) errors		
N.	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3
c1	25.0%	30.4%	10.0%	85.7%	73.3%	83.3%
c2	9.5%	4.5%	8.0%	57.9%	80.0%	90.5%
c3	3.6%	4.0%	5.0%	63.2%	72.7%	69.0%
c4	13.6%	18.2%	35.3%	74.1%	57.1%	78.9%
c5	0.0%	15.0%	0.0%	66.7%	85.7%	88.5%
c6	3.7%	3.4%	4.3%	68.8%	83.3%	85.7%
c7	12.0%	13.3%	0.0%	70.0%	75.9%	65.0%
c8	0.0%	10.5%	4.2%	75.0%	92.6%	72.7%
M	**8.7%**	**10.8%**	**9.2%**	**70.2%**	**77.6%**	**79.2%**
SE	**2.0%**	**2.0%**	**2.7%**	**3.0%**	**3.8%**	**3.3%**

Note. Task performance of each subject, as assessed by the errors made when the white dot in the second-link search task was visible (actual errors; first column) and not visible (perceived errors; second column).

Percentage of total errors was relatively stable across phases (M_1 = 44.8%, *SE* = 2.5% in the baseline phase, M_2 = 42.1%, *SE* = 3.5% in the manipulation phase and M_3 = 42.1%, *SE* = 3.6% in the reversal phase) and no significant statistical differences were observed, $\chi 2(2) = 2.50$, $p = .882$, $W = .02$. Two special cases should be also mentioned at this point. In Phase 3, subject e4 and c4 made a greater number of detection errors in the "visible white dot" trials (42.9% and 35.5% respectively) than in the other two conditions. Although this does not imply lack of interest, as points earned were relatively high and lag failures relatively low in both cases, it could be argued that actual detection errors functioned as an additional punishment source that might have evoked different stereotypy/variability patterning. However, if this was the case it would be expected that stereotypy levels of subject e4 would have remained relatively increased in Phase 3 compared to Phase 2 and certainly not returned to baseline levels (see Table 8). Therefore, it is reasonable to assume that after the cessation of point-loss threat, the negative reinforcing potency of detection errors in the search task was decreased, whereas in the control group, increased actual detection errors did not have any particular effect in stereotypy patterning levels.

In the post-experimental semi-structured interviews, none of the participants understood or guessed spontaneously or when directly asked, the white dot deception. Also, all of the experimental group subjects reported the transition from the no-point-loss context in Phase 1 to the point-loss context in Phase 2 and eventually its reversal in Phase 3. Thirteen subjects did not describe the lag contingency explicitly, although they identified that patterning in the first-link task was relevant to the production of the open or locked padlock icon. The other three (e4, c3, c6) reported that they understood the lag contingency.

Discussion

Conceptual and experimental analysis of punishment mainly focuses on its functionality of reducing the frequency of a particular response due to its consequences (e.g., Azrin & Holz, 1966; Cooper et al., 2020). Indeed, the decrease in the emission frequency of a punished response form is a common effect of punishment operations, including the reduction of emission of problematic and dangerous forms of behavior in applied contexts (e.g., Lydon et al., 2015). However, defining punishment exclusively based on this effect, omits the decisive role of several functions of presenting a negative reinforcing stimulus or terminating a positive reinforcing stimulus as a consequence of behavior. Therefore, the general goal of the current study was to examine the importance of these overlooked phenomena by observing the effect of the punishment of one form of behavior on the stereotypy or variability of a second form of behavior, namely the variety in patterning of serial fixation eye movements.

One of the effects that are undervalued and understudied in the experimental and applied behavior-analytic literature is the potential of punishing conditions to evoke behaviors that have terminated punishment in the past. Specifically, due to temporal pairing between the aversive conditions and the punished responses, the stimuli produced by the latter may acquire negative reinforcing potency and function as warning signals (e.g., Sidman, 1953, 1962, 2000). As a result, the stimuli produced by these punished responses will tend to evoke behaviors that have terminated them in the past, thus, facilitating the increase in the frequency of emission of unpunished forms of behavior. In other words, because the stimuli produced by unpunished responses are wholly incompatible with the stimuli produced by punished responses, the former will tend to be evoked in a threatening context in lieu of the latter.

After the escape from the warning signals (e.g., in a warning signal avoidance procedure), the contextual stimuli produced are inevitably paired with the termination of the threat and may acquire positive reinforcing potency in threatening environments (Dinsmoor, 2001a; Mellon, 2013b). As a result, similar threatening/punishing conditions will tend to evoke the emission of ‘safe’ action patterns, even before the subject’s behavior has actually been punished. Often trivialized as a “side effect,” (see also Edwards & Poling, 2020; Fontes & Shahan, 2020; Holth, 2005), the evocation of behavioral patterns that are incompatible with the emission of punished patterns is in fact a significant effect of punishment procedures which, in some cases, may be beneficial for subjects’ lives but in others may hamper their access in vital social and non-social reinforcing stimuli.

More recently, punishment has also been classified as a ‘motivating operation,’ in the sense that the presentation of certain types of conditional aversive events ‘make their own termination effective as a reinforcer’ and therefore increase the tendency to behave in a way that terminates them (Laraway et al., 2014). However, although this formulation (at least indirectly) attempts to focus on the evocative effect of a punishing context, it does not shed any light on the stimulus control mechanisms underlying the reduction of the frequency of the relevant responding rate. Furthermore, by assuming a direct relation between aversive stimulation and behavioral manifestation, the importance of the individual repertoire of the subject is inevitably underestimated.

Therefore, the first experiment reported here, aimed to isolate the discriminative properties of social punishment on levels of visual-motor stereotypy/variability in the absence of differential reinforcement of stereotypy/variability. For this purpose, an experimental task was designed, which included two different subtasks in the form of an operant chain. In the first task (serial fixation task), subjects were instructed to produce eye movement patterns by sequentially fixating on four different points on the screen. Afterward, they had to detect a small-scale stimulus (a white dot) that momentarily appeared in the screen under a VI schedule and choose its correct location. Throughout the experimental task, if they correctly detected the stimulus location, they gained points. However, the reinforcement contingency for failed detections changed across the three phases of the experiment. Specifically, in the first (baseline) and the third (reversal) phases, detection errors did not any event other than the onset of the next trial, whereas in the second (manipulation) phase, 10 points were deducted for each detection error accompanied by a relevant gaming-failure sound and a change in the font color of the points font white to red.

Although in 50% of the trials, the stimulus change was relatively easy to detect, in the other 50% of the trials it never actually occurred. This manipulation ensured that subjects would make quite a high and stable number of perceived errors during the task, errors that would be punished in the second phase of the experiment, while the stereotypy or variability of the visual-motor fixation patterns produced in the first-link task were recorder but neither reinforced nor punished with any programmed consequence. The experimental design concerning the above rationale was successful as performance on the detection task was significantly reinforced when stimulus change was easily detected and infrequently reinforced when the stimulus change did not actually occur. This afforded an assessment of the possible change of stereotypy/variability levels of subtask 1 fixation patterning due to the implementation of the punishing contingency in subtask 2, as visual-motor patterning was functionally independent of the consequences of action in the second subtask.

Indeed, a relatively systematic trend was observed in most subjects (for discussion about exceptions, see below), as indicated by multiple measures of stereotypy. Specifically, in the second phase, where detection errors were punished with point-loss and other relevant consequences, subjects tended to produce more stereotypic fixations patterns than in the first phase. However, this trend was then reversed in the third phase as almost all of the subjects that behaved *more* stereotypically in Phase 2, behaved *less* stereotypically in Phase 3. This fluctuation in levels of topographic stereotypy was indicated statistically but most importantly by examining the individual data of each subject.

Interpretations of the observed phenomenon

Four different interpretations could be offered to explain this alternation in the experimental group subjects' responding pattern. First of all, although first and second-link tasks lead to the production of different conditional reinforcement stimuli (open padlock and points respectively), they share several common "sensory" and "contextual" characteristics. Both of them require vigilant eye movement behaviors as well as processing of auditory stimuli (i.e., relevant sound effects), and their experimental environment was nearly identical. Therefore, it is reasonable to suggest that the escalation in stereotypy levels in the first-link pattering task in Phase 2 was a result of generalized differential reinforcement of stereotypic visual-motor behavior occurring in the second-link search task. In other words, it could be argued that subjects tended to emit more repetitive visual-motor sequences in Phase 2 when searching for the white dot, and either coincidentally or not, this relatively repetitive responding led to increased point-gaining and eventually was generalized to the first-link task fixation patterning. Unfortunately, due to the low frame rate of the eye-tracker, accurate and valid saccadic recording was not possible in the second-link subtask; thus it was not possible to test for this hypothesis. However, even if this was the case, the hypothesized increase in stereotypy when searching for the white dot was not more effective, as is evident by the relevant point-gathering and point-loss data which were presented above. Therefore, generalized differential reinforcement cannot be assumed because there was no increase in the reinforcement rate or decrease in the punishment rate across conditions.

A second interpretation was that for reasons other than the implementation and the removal of the punishment imposition, subjects tended to behave more stereotypically in Phase 2 and more variably in Phase 3. For example, it is well known that tasks that require extended concentration and attention skills may lead to performance deterioration over time (i.e., vigilance decrement effect, e.g., Körber et al., 2015; see Warm et al., 2018). Thus, it could be argued that the optical pattern variability was restricted in Phase 2 of the experimental group due to fatigue and then was somehow restored in Phase 3. However, this alternation in subjects' responding patterns did not appear in the second group of participants (i.e., a control group), which was exposed to the same task parameters but without the programmed punishment contingency in Phase 2. Furthermore, variability levels in fixation patterning in the control group were quite heterogeneous across phases, and in any case, no systematic (statistical or visual) trend was observed. Therefore, this interpretation is also not supported by the available evidence.

Another possibility is that subjects' behavior in the punishing conditions was mediated by covert verbal behavior that could not be identified otherwise. It is possible for example, that when participants received the point-loss punishment, they attempted to cope with the increased aversiveness of detection errors by thinking and implementing strategies that could not be recorded in the experimental session. Indeed, some of the subjects (in both experiments) reported during the semi-structured post-experimental interview that they implemented tactics in order to be more effective in the search task. For instance, some reported fixating their gaze in the middle of the left or right part of the screen (i.e., between the two black dots) in order to be sure that they will detect the white dot with 100% probability if it appeared inside these two black dots and subsequently have 50% if they did not spot it and guessed its location in the other two possible sites. Of course, it cannot be determined whether they started using this type of strategy before or after the application of point-loss punishment, but presumably, when detection errors were negatively punished by point-loss, subjects may have generated verbal self-instruction to cope with the threatening condition. Therefore, because responses in the second-link task became more complex (as well as more crucial), varied fixation patterning in the first-link task may have lost reinforcing potency, favoring the reproduction of the most prevalent patterns. However, even if this was the case, visual-motor stereotypy levels should have been stable in the reversal Phase 3 for the experimental group (or even further increased) as such verbal behavior might have somehow facilitated subjects' performance.

A final interpretation is based on the theoretical framework that defines punishment as a complex procedure that has several effects on behavior. One of them is the potential to evoke certain forms of responding, when doing so, reduces or eliminates contact with unconditional or conditional negative reinforcing stimuli. However, in the current task, visual-motor stereotypy in the first-link patterning subtask did not have any scheduled effect on removing aversive consequences in the second-link subtask. Therefore, its evocation is likely a generalized effect of pre-experienced negative reinforcement contingencies, in which responses outside a specific operant class are punished, whereas responses that match the last emitted responses not only remain unpunished but terminate the conditional negative reinforcing stimuli automatically produced by the punished actions.

When response-form variability is not differentially reinforced, the topography of emitted responses within an operant class is well known to become more stereotypic over time (e.g., Antonitis, 1951; Page & Neuringer, 1985; see Balsam et al., 1998 and Lee, 2007 for reviews). This pattern is obvious in the increase in stereotypy levels of visual-motor fixation patterning of the control group (see Figure 4). However, in the experimental group, this increase was steeper, and most importantly, it was *reversed* in the majority of the subjects in the return-to-baseline Phase 3, isolating the evocative effect of punishing conditions in a relatively independent link of the operant chain.

Of course, some participants of the experimental group did not exhibit higher levels of visual-motor stereotypy in the second phase (depending on the measure of stereotypy). Moreover, some did *not* exhibit lower levels of visual-motor stereotypy after the cessation of the threat of point-loss punishment in the reversal phase. Indisputably, the evocative effect of punishing conditions, as for any other contextual stimulus, depends on the individual history of each subject. For example, if repetitive responding had been punished in the past, whereas auto-differentiation had been negatively reinforced, contact with threatening or/and punishing consequences could have instead evoked generalized visual-motor variability. This latter interpretation fits well with the data and explains satisfactorily both group and individual variance differences in gross eye movement fixation patterning.

An issue that appeared while conducting Experiment 1 was that some subjects exhibited extremely high levels of stereotypy even from the outset of the baseline phase. As a result, it was difficult to observe the extent to which the punishment of detection errors increased stereotypy in fixation patterning in the first-link task (i.e., ceiling effect). In order to cope with this difficulty, a DRV schedule (lag 1) was applied in the first-link task in Experiment 2. Again, the second experiment aimed to get a clearer image of the discriminative function of the same punishment contingency on gross eye movement stereotypy/variability levels in the absence of differential reinforcement of stereotypy/variability. Moreover, Experiment 2 investigated the role of subjects' learning history (specifically, exposure to DRV), which may mediate the relation between the punishing context and behavioral stereotypy/variability.

First of all, the implementation of the lag 1 criterion was successful in that subjects of both groups (experimental and control) had showed significantly higher levels of variability by the end of the first phase compared with subjects of Experiment 1, where there were no requirements of topographic auto-differentiation for proceeding to the second-link task. Although this finding was expected, it is noteworthy to mention that this is the first time that gross eye movement-patterning variability is controlled by its reinforcing consequences in experimental settings. Unexpectedly, the results had a different direction than the results of Experiment 1.

Specifically, by inspecting group and individual data (see Table 8), it is evident that after the transition to the point-loss context of the manipulation phase, subjects tended to produce *more* rather than *less* variable visual-motor fixation patterns compared with the baseline phase. This pattern was partially reversed in the return-to-baseline phase when the point-loss contingency was not further applied. In essence, the responding pattern in Experiment 2 was the opposite compared to Experiment 1, and this trend was not observed in the relevant control group. Although these results were less robust (both visually and statistically), reinforcing the production of different visual-motor pathways in the first subtask inhibited the stereotyped fixation patterning evoked by point-loss punishment in Experiment 1.

We cannot, of course, conclude that punishment operations do not evoke stereotypy after exposure to DRV conditions. If this was the case, it would be expected that the results of both experimental and control groups would be similar, if not identical. Instead, it shows that punishing conditions can, similarly with Experiment 1, alter stereotypy/variability levels of visual-motor patterning in a concatenated context by evoking certain responses that tended to be emitted in the recent past, even if the relevant links of the operant chain are not functionally related. It also stresses the importance of the individual learning history of each subject because, in contrast with the free operant conditions of the first experiment, in the second experiment, the interaction with the DRV conditions was enough to change the direction of the evocative effect of punishment: In Experiment 1, where subjects produced patterns in the absence of DRV criterion, punishing conditions tend to *increase* stereotypy levels of fixation patterning in the first-link task whereas in Experiment 2, where they learned to vary, punishing conditions tend to *decrease* stereotypy levels of fixation patterning in the first-link task. In both cases, punishment operations increased the frequency of responses that tended to be emitted in the recent past and were not punished.

Significance and application of the results in clinical contexts

This interpretation, which is based on a molecular analysis of punishment (e.g., Mellon, 2013a, 2013b), may help clarify and elucidate similar complex phenomena that involve punishment procedures, and especially phenomena in which responding in earlier links is affected by punishment operations in subsequent links of the operant chain. Furthermore, the conceptual appreciation of the multiplicity of punishment effects may further help identify and control the involved processes in various socially significant cases in the subject's best interests (see Baer et al., 1968, 1987). As noted at the Introduction, atypical visual-motor patterns (often called “deficits”) are manifested in numerous clinical populations (see Bueno et al., 2019; Falck-Ytter et al., 2013). For instance, it has been repeatedly indicated (e.g., Manyakov et al., 2018; Sasson et al., 2008; Schwartzman et al., 2015) that children diagnosed with ASD exhibit atypical and sometimes “maladaptive” eye movement behaviors by attending for more extended periods on certain non-social stimuli (e.g., trains, planes, road signs and others) compared to social stimuli (e.g., happy human faces). Beyond focusing solely on the region or the duration of gazing, these behavioral manifestations can also be conceptually and experimentally analyzed in terms of low/high eye movement stereotypy/variability. In essence, when a number of visual stimuli are presented in a certain context and a subject is mainly fixating only on half of them (e.g., by alternating between non-social and ignoring social images), he/she exhibits visual-motor stereotypy. Similar conceptual analysis may be applied when subjects maintain long-lasting eye contact with certain non-social stimuli and subsequently very brief eye contact with social stimuli. This atypical visually guided behavior may be examined in terms of high eye movement stereotypy patterning in relation to a history of differential punishment and negative reinforcement.

Stereotypy/variability levels in several sensory domains may be altered when subjects are exposed to DRV procedures which may involve a variety of schedules of reinforcement that can be implemented for this purpose (Neuringer, 2002), as in the first-link fixation patterning task of Experiment 2 in the current study. However, beyond the differential reinforcement (e.g., Galizio & Odum , 2022) or differential punishment (Fonseca Junior & Hunziker, 2017) of stereotypy/variability, the current study focuses scientific attention in the context that seemingly have no functional relation with stereotypy/variability levels. As demonstrated in the above experiments, the evocative effect of punishment may change stereotypy levels even when applied in different behavioral links. This finding may be helpful in cases where the clinician/teacher/parent implement punishment operations in order to decrease certain forms of behavior, as it stresses the fact that threatening conditions may have effects that are not restricted to frequency reduction in the relevant operant link but may be extended to other links, in which changes in stereotypy levels are not beneficial for the subjects. For example, when teaching individuals diagnosed with ASD to visually attend social stimuli, it would be better for them to be taught by a practitioner that is not associated with punishing contexts; otherwise the practitioner’s presence is likely to evoke stereotypy in eye movement patterns (i.e., to fixate more on non-social stimuli).

However, the relationship explicated above between the evocative effect of punishment and stereotypy levels is not direct. Instead, it depends on the relevant differential reinforcement and extinction history of each individual. As indicated by the second experiment, when subjects learned to produce variable patterns of visual-motor movements, the evocative effect of stereotypy was inhibited or reversed; indeed, a punishment-evoked *increase* in variability was observed in most subjects. Therefore, it is incorrect to assume a direct and unmediated relationship between punishment operations and behavioral variability (e.g., Laraway et al.,

2014) without considering the subject's individual repertoire and the relevant stimulus control processes involved in each case.

This finding may be useful in therapeutic contexts where the clinician/teacher/parent does not want to collaterally increase stereotypy levels in adjacent links of the operant chain. For example, children diagnosed with Fragile X syndrome (FXS) exhibit a relatively low frequency of eye contact with others (Hall et al., 2006; Hall et al., 2009). Specifically, they tend to avoid looking at the eyes of human figures with whom they interact. Again, the avoidance operations may be conceptualized in terms of low eye-movement variability in the sense that in the presence of human faces, they terminate the contact with this warning stimuli by repeatedly (i.e., stereotypically) shifting their gaze to directions other than the relevant face. It seems that additional punitive stimuli may further hinder the occurrence of variable behavior even if they are presented as consequences of irrelevant behaviors that are manifested in the same operant context. Furthermore, learning to vary in this context may reduce or reverse this evocative effect of punishment, favoring the emission of higher levels of visual-motor variability.

In both of the aforementioned disorders (ASD and FXS), problematic stereotypy levels of eye movement-patterning have long-term as well as short-term negative consequences for the social and “cognitive” development of affected individuals. However, it should not be implied that increased variability benefits any other typical or atypical behavioral manifestation. For instance, when patients diagnosed with Alzheimer’s disease perform orienting and navigational tasks, they are found to attend more than the typical population to stimuli that are not relevant to their relevant object (e.g., Davis & Sikorskii, 2020). In opposition to the cases of ASD and FXS, the increased tendency to look to stimuli that are not relevant to their destination may be partially considered as a highly variable visual-motor patterning behavior (see Molitor et al., 2015). In this regard, punishing conditions are expected to increase further ocular variability levels, which will subsequently hamper their functionality even more.

Likewise, difficulties in sustaining attention that are observed in individuals diagnosed with ADHD may be affected by punishment operations and the processes that they affect. It has been shown, for example, that children with ADHD maintain their fixation on stimulus changes for shorter time periods compared to typically developed children (e.g., Türkan et al., 2016). Inevitably, shorter fixation periods to the regions of interest means fixations for *longer* periods to *irrelevant* regions, which is ultimately an indicator of highly variable visual-motor responding. Based on the results of Experiment 2, it is expected that the presence of threatening and punitive stimuli may further raise these variability levels even if those punishing stimuli are presented in preceding links of the operant chain.

Limitations and suggestions for further research

As indicated and discussed previously, the evocative effect of point-loss punishment was not universal across all subjects and stereotypy measures. For instance, a few subjects in Experiment 1 did not behave more stereotypically in the punishment phase and few subjects in Experiment 2 did not behave more variably in the same phase, whereas some subjects of the control groups produced similar responding pattern across phases as their respective experimental groups. Moreover, the effects of second-link punishment on first-link variability in fixation patterning levels in Experiment 2 were not statistically reliable with all measures. In order to understand these findings and increase their clarity, methodological limitations of the current experimental design should be identified, and relevant directions for further improvements should be proposed in parallel.

Specifically, several technical parameters may have limited observed effects of the independent variable. First, an order effect was observed the majority of the subjects of both experiments which was manifested by producing patterns that started from the upper left corner at the four-dot display. Although the equality of frequencies of the 24 available patterns was not prerequisite for testing the evocative effect of punishing conditions, it is plausible that a less biased form of responding would have produced more robust and more apparent results. For example, a different sensory domain of responding (e.g., vocal) would help reduce this bias. Likewise, a refinement of the current task where the available fixation points (i.e., black dots) were in different positions (e.g., forming a conceivable circle) might induce less the occurrence of an order effect.

Another notable technical issue in the first experiment was the ceiling effect of stereotypical visual-motor patterning during the first-link task. For example, subjects e4, e11, c5, c9 and others of the first experiment produced the most prevalent pattern in Phase 1 in more than 90% of the trials, and some of them (e.g., e4, e6, e10) reached the maximum possible frequency by producing the two most prevalent patterns in 100% of the trials. This fact inevitably restricted the potential effect of the independent variable to be expressed. Presumably, this tendency would be reduced by increasing the available fixation points (e.g., from four to eight), because subjects would have more S^Ds to produce intentionally or accidentally different patterns (note that a more accurate and precise eye tracking device than the one employed in the current study is needed for this adaptation).

Regarding the study design, a more extended test of the effect of punishing conditions with an ABAB design in combination with a more intensive analysis of each individual would be experimentally more robust. These changes would of course, require an increase in the total number of trials and, subsequently in the total duration of the experimental task, something that is relatively difficult due to the already high levels of task-induced fatigue. Therefore, in order to increase the number of trials, the task would need to be redesigned in a simple/ faster version either by reducing the available fixation points from four to three (however, see the above paragraph regarding order effects) or by reducing the requisite time of each black dot fixation (e.g., from 300 ms to 200 ms).

Furthermore, although it is reasonable to assume the punishing context in the ABA groups functioned as a negative reinforcing stimulus due to the pre-experimental history of the subjects in video-games and other similar audiovisual tasks, there was no experimental evidence that it indeed had negative reinforcing potency. During the post-experimental interview, subjects mentioned (mainly spontaneously) the point-loss condition, along with the failure sound and the change of color in the point counter, was a highly punitive stimulus, but to ensure that this compound stimulus indeed has negative reinforcing potency for all participants, an extra task would be required prior the initiation of the main task, again increasing vigilance fatigue in later exposure to the experimental task.

In general, although the task employed was quite simple for subjects to perform, it was still a complex operant chain that engaged several processes and reinforcing stimuli that might have had an unobserved effect in different links of the chain. For example, subjects might have implemented strategies in any of the subtasks that might have been proved effective (e.g., faster detection of the white dot) but could not be observed and/or recorded by the eye tracking device. It is suggested that the phenomenon of interest should be studied in simpler tasks that also consider or even control subjects' concomitant verbal behavior.

Experiment 2 also had three more methodological issues, which could have limited the reliability of the observed effects. First of all, due to COVID-19 restrictions, only eight individuals participated in each group and it is well known that small samples increase the probability of Type II error. It should also be noted that subjects of the second experiment were exposed fewer times in the punishment contingency compared to the subjects of the first experiment because when they failed to meet the lag 1 criterion, they did not proceed to the visual search task but to the following trial. Both of the above issues can be solved by increasing the sample size and the quantity of trials, respectively. Furthermore, the lag schedule inevitably involved an additional punishment operation compared to the free operant context of Experiment 1, in the sense that lag failures were punished with the image of the locked padlock (see Figure 5), which signaled the start of the following trial (blocking their opportunity to gain points in the visual search task). Subsequently, it is difficult to dissociate between the effect of each punishment procedure (lag failure and point-loss contingency) on visual-motor fixation patterning. This issue could be possibly resolved if the lag schedule is applied in an additional phase in the beginning of the experiment and then is removed during the ABA’ phases (though it is uncertain if variability levels will be maintained during the ABA’ phases). In any case, the above limitations of both experiments do not undervalue the findings of the current study or their observed systematic nature. They should however be carefully considered in order to afford a more robust examination of the evocative effect of punishing conditions on stereotypy/variability levels of human behavior.

A social punishment procedure was found to alter stereotypy/variability levels in a gross eye movement fixation patterning task when the punishment contingency was applied in the subsequent link of the operant chain (i.e., visual search task). Moreover, the direction of this change depended on the individual reinforcement history: in the absence of specific reinforcement criteria, the punishment procedure in the second-link task evoked higher levels of stereotypic responding. Under DRV criterion, punishment of visual detection errors tended to evoke higher levels of *variable* fixation patterning. These findings highlight the importance of a more analytic formulation of punishment operations (Dinsmoor, 1988; Keller & Schoenfeld, 1950; Mellon, 2013a, 2015; Sidman, 2001; Skinner 1953, 1971; see also LeDoux et al., 2017) which may be subsequently more effective in clinical as well as non-clinical settings where behaviors based on eye movements play a crucial role in the life of individuals. Unfortunately, in several of these contexts, punishment does not just remove points from a point counter or produce aversive gaming sounds; rather, it terminates moments of happiness, calmness, and opportunities for socially appropriate contact with others and produces disapproval, marginalization, or even worse, public shaming and physical attack. In order to understand those destructive effects on human and non-human behavior, a more thorough conceptual analysis and experimental investigation of punishment operations is warranted.

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Appendix A

Informed consent form

Below is the informed consent form text (in Greek) which each participant read and signed prior to the initiation of the experimental procedure:

Καλείστε να συμμετάσχετε σε μια επιστημονική έρευνα που διεξάγεται στα πλαίσια εκπόνησης διδακτορικής διατριβής στο Τμήμα Ψυχολογίας του Παντείου Πανεπιστημίου Κοινωνικών και Πολιτικών Επιστημών.

Σκοπός της έρευνας είναι μελέτη της ανθρώπινης αντίληψης και προσοχής.

Η συμμετοχή σας στην έρευνα είναι εθελοντική ενώ τα δεδομένα που θα συλλεχθούν θα είναι πλήρως ανωνυμοποιημένα ενώ διασφαλίζεται η εμπιστευτικότητά τους. Μετά το τέλος της πειραματικής διαδικασίας, θα ακολουθήσει αναλυτική ενημέρωση σχετικά με τη συνολική ερευνητική διαδικασία.

Έχετε το δικαίωμα να διακόψετε τη συμμετοχή σας στην έρευνα οποιαδήποτε στιγμή το επιθυμείτε χωρίς καμία συνέπεια/κύρωση και χωρίς να υπάρχει η ανάγκη αιτιολόγησης της πράξης αυτής.

Για τυχόν απορίες ή ερωτήσεις που θα προκύψουν, μπορείτε να απευθυνθείτε στον υπεύθυνο ερευνητή, κ. Διάκο Στέφανο.

Έχω διαβάσει τις παραπάνω πληροφορίες και συμφωνώ να συμμετέχω στη συγκεκριμένη επιστημονική έρευνα.

Ονοματεπώνυμο συμμετέχοντος/ουσας στην έρευνα:

Ημερομηνία:

Υπογραφή:

Appendix B

Photos of all possible conditions generated during the experimental task

Figure B1

Initiation of the task: central fixation (same in both experiments)

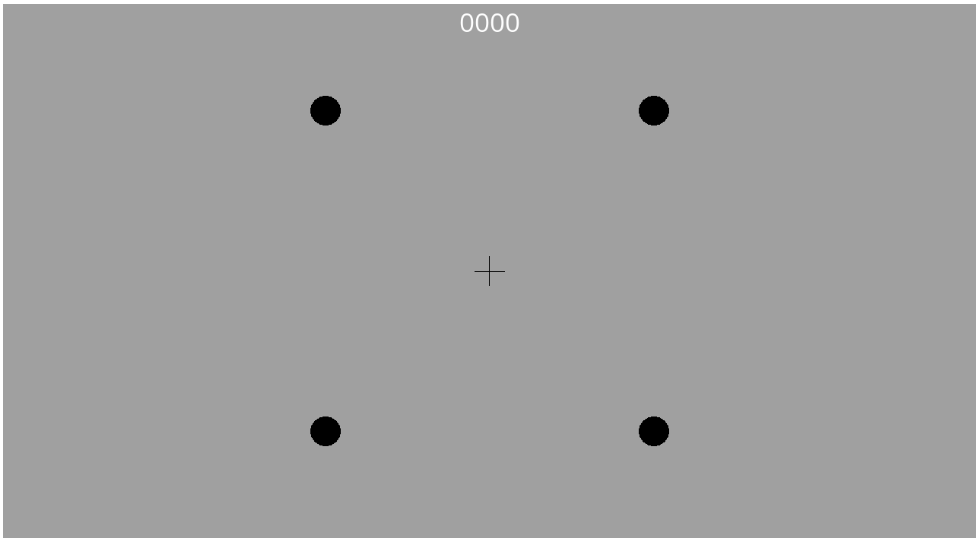

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Figure B2

Serial fixation patterning task (same in both experiments)

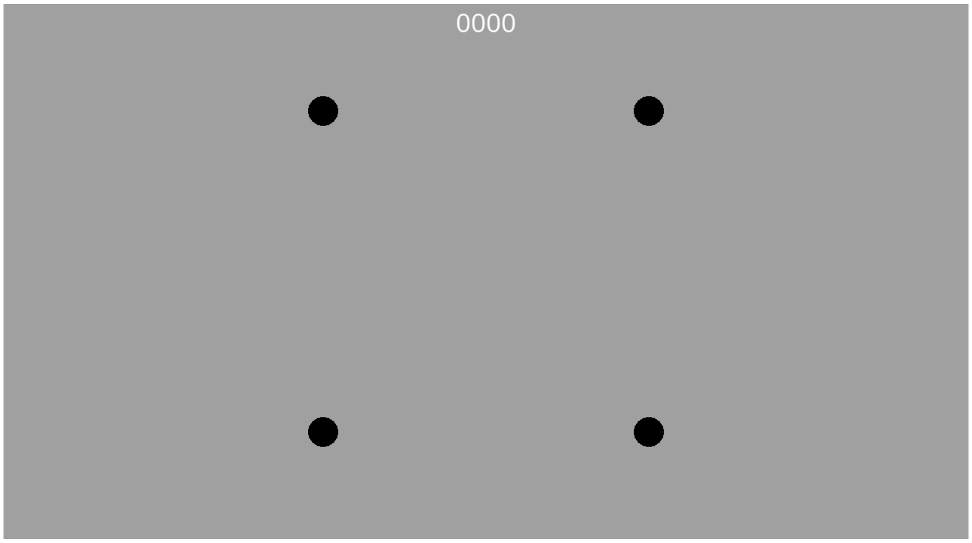

Figure B3

Fixation completion feedback (in any case in Experiment 1 and only when DRV 1 criterion was met in Experiment 2)

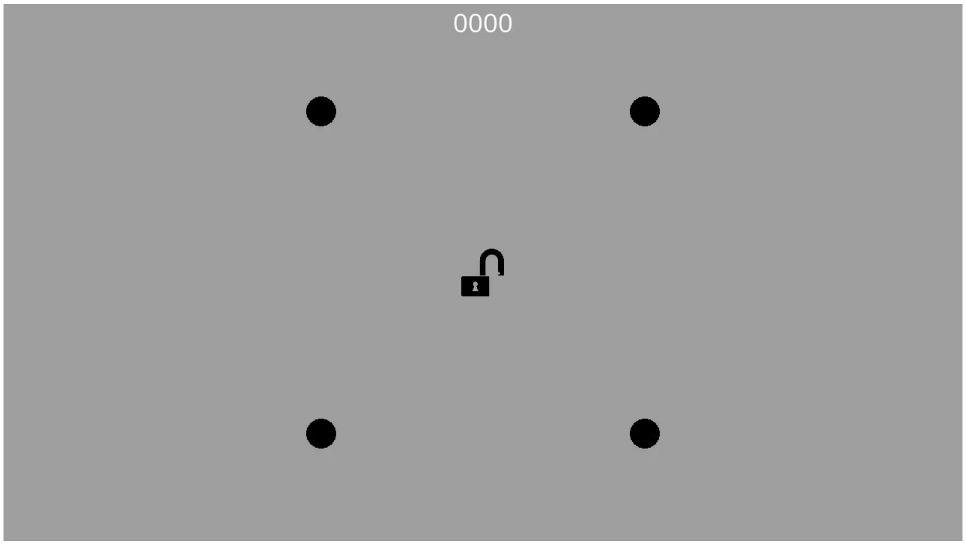

Figure B4

Fixation completion feedback (when DRV 1 criterion was not met in Experiment 2)

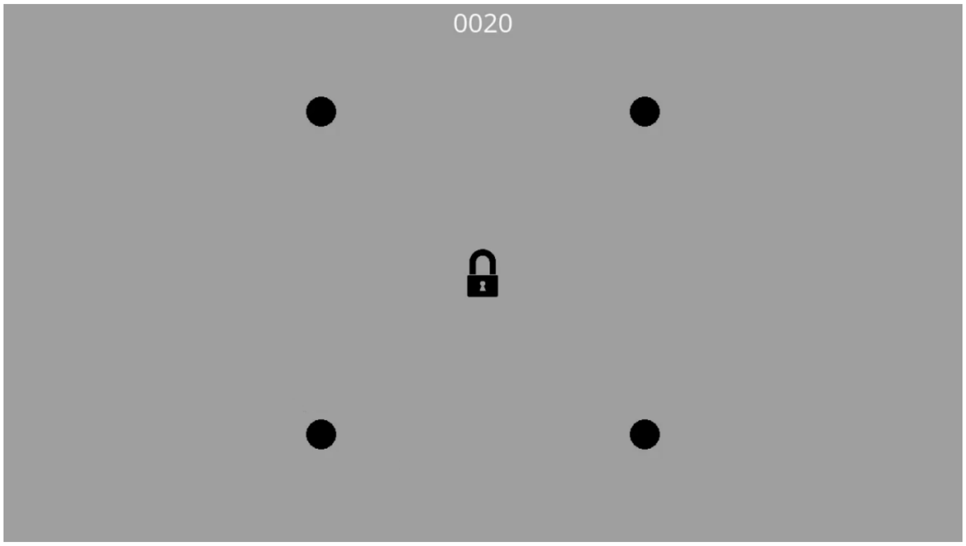

Figure B5

Search task (same in both experiments); white dot is in the lower left black dot

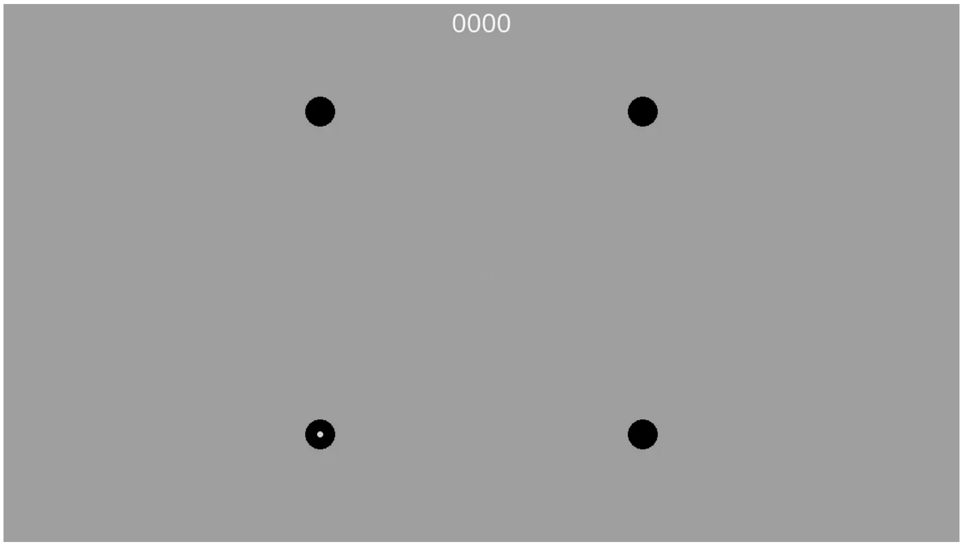

Figure B6

Mouse-click detection response task (same in both experiments)

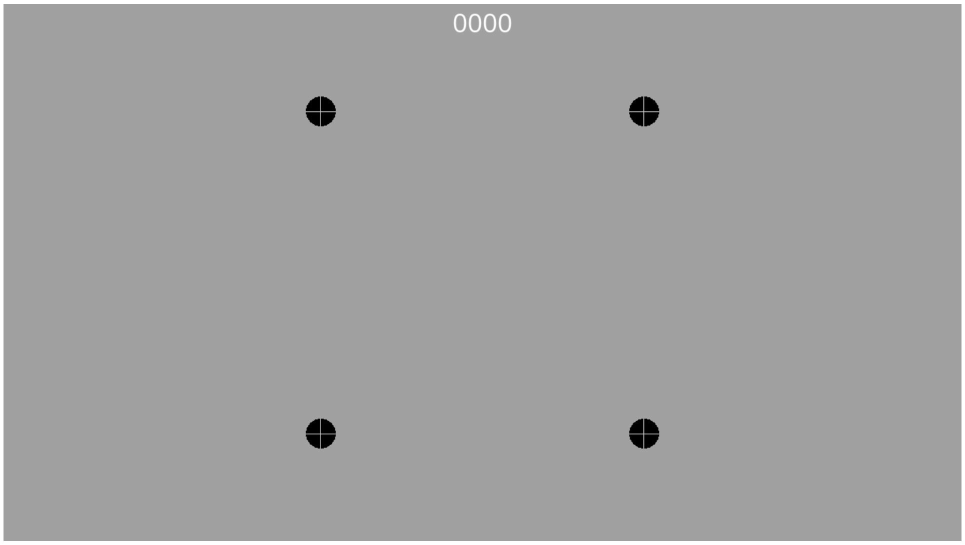

Figure B7

Response feedback: 10 points added to the counter (same in both experiments)

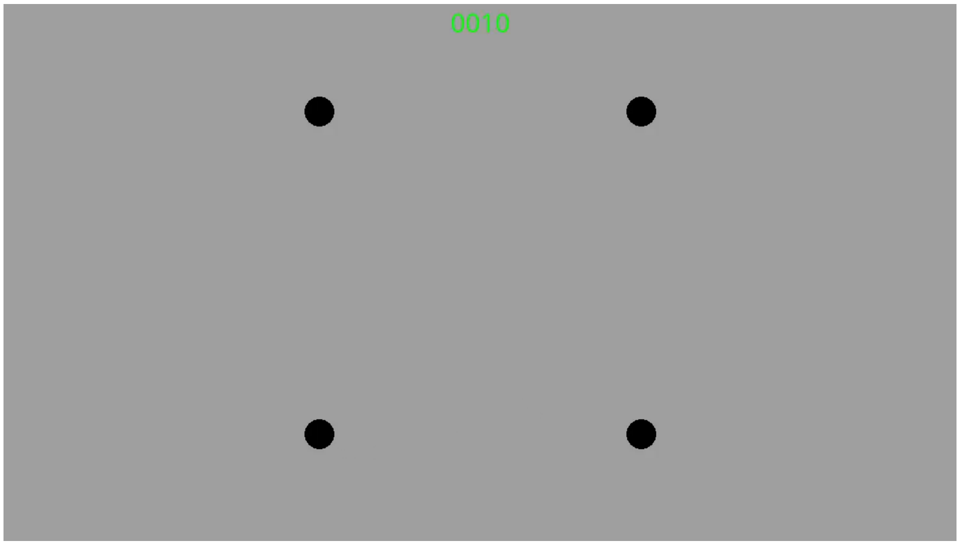

Figure B8

Response feedback: 10 points removed from the counter (same in both experiments)