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The effect of stimulus intensity on response time and accuracy in dynamic, temporally-constrained environments

Joe Causer
The University of Sydney

Allistair McRobert
Liverpool John Moores University

A Mark Williams

The University of Sydney

Liverpool John Moores University

Please address correspondence to:

Dr Joe Causer

Discipline of Exercise and Sports Science

Faculty of Health Sciences

Cumberland Campus

The University of Sydney

East Street Lidcombe

NSW

Australia 2141

Tel - +61 2 9351 7241

Fax - +61 2 9351 9204

Email – joe.causer@sydney.edu.au

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RUNNING HEAD: Stimulus intensity and performance

Abstract

The ability to make accurate judgments and execute effective skilled movements under severe temporal constraints is fundamental to elite performance in a number of domains including sport, military combat, law enforcement, and medicine. In two experiments, we examine the effect of stimulus strength on response time and accuracy in a temporally-constrained, real-world, decision-making task. Specifically, we examine the effect of low stimulus intensity (black) and high stimulus intensity (sequin) uniform designs, worn by teammates, to determine the effect of stimulus strength on the ability of soccer players to make rapid and accurate responses. In both field- and laboratory-based scenarios, professional soccer players viewed developing patterns of attacking play and were required to make a penetrative pass to an attacking player. Significant differences in response accuracy between uniform designs were reported in laboratory- and field-based experiments. Response accuracy was significantly higher in the sequin compared to the black uniform condition. Response times only differed between uniform designs in the laboratory-based experiment. These findings extend the psychophysics literature into a real-world environment and have significant implications for the design of clothing wear in a number of domains.

Key Words: Perceptual-cognitive expertise; perception; sportswear design; attention

Introduction

In many domains such as law enforcement, medicine, the military, and sport, decisions have to be processed and executed under severe temporal pressure. In such situations, individuals have to develop strategies or processes to pre-empt, or anticipate the actions of others (e.g., opponents and teammates). An extensive body of research now exists to suggest that experts develop more refined perceptual-cognitive skills that facilitate anticipation and decision-making when compared with less expert or novice counterparts. These perceptual-cognitive skills include: a) the more effective use of visual resources when scanning the environment (cf. Williams, Ford, Eccles & Ward, 2010); b) the ability to pick up advance (i.e., pre-event) information from the postural orientation and actions of an opponent (Abernethy & Russell, 1987; Jones & Miles, 1978); c) a capacity to recognise familiarity and structure based on the relational information that exists between teammates and opponents (North, Williams, Hodges, Ward & Ericsson, 2009; Williams, Hodges, North & Barton, 2006); and d) the capability to accurately predict the likely choice options open to an opponent at any given moment based on the availability of context-specific knowledge (Crognier & Féry, 2005; McRobert, Ward, Eccles & Williams, 2011). The relative use and importance of these perceptual-cognitive skills are thought to fluctuate in a dynamic manner based on the unique constraints of the performance context (Williams et al., 2010; Williams, 2009).

Perceptual cognitive skill refers to the ability to identify and acquire environmental information for integration with existing knowledge such that appropriate responses can be selected and executed (Marteniuk, 1976). Knowing where and when to look is crucial for successful performance in many domains and tasks, yet the visual display is vast and often saturated with information both relevant and irrelevant to a given task. Performers must identify the most information-rich areas of the display, direct their attention appropriately, and extract meaning from these areas efficiently and effectively (Williams, Davids, & Williams, 1999). In the current paper, we examine the role of attentional orientation on response time and response accuracy in a dynamic, temporally-constrained environment.

Jonides (1981) identified two types of attentional orienting: endogenous and exogenous orienting. Endogenous or top-down orientating is centred on the dorsal posterior parietal and frontal cortex and involves the cognitive selection of sensory information and responses. Exogenous or bottom-up orientating is centred on the temporoparietal and ventral frontal cortex and is recruited during the detection of behaviourally relevant sensory events (Corbetta & Shulman, 2002). The documented effects of spatial cues on performance using target stimuli that subsequently appear at the cued or uncued locations suggest that separate processes are involved in endogenous and exogenous shifts of attention (Muller & Rabbitt, 1989; Nakayama & Mackeben, 1989). Centrally located cues only facilitate performance at the cued location when the cue provides information about the subsequent target location (endogenous orienting), while peripheral cues facilitate performance even when the cues provide no information about target location (exogenous orienting) (Posner & Cohen, 1984; Posner, Choate, Rafal & Vaughn, 1985).

The facilitation produced by sensory cues appears more rapidly (within 50 ms) than that produced by cognitive cues (Posner & Cohen, 1984; Muller & Rabbitt, 1989). These stimulus-driven shifts of attention (Corbetta & Shulman, 2002) may occur to highly salient sensory stimuli that are irrelevant to the current task, such as a light in the periphery field of vision (Posner & Cohen, 1984). However, sensory stimuli attract attention more effectively when they are relevant to the current task, or when they share attributes with target stimuli, such as a red bus while looking for a red car (Folk, Remington & Johnston, 1992). This latter type of orientation has been labelled ‘contingent’ as it emphasises the relevance of stimulus features rather than their sensory salience (Folk, Leber & Egeth, 2002).

An individual's reaction time to a visual stimulus represents the total time taken for a cascade of neural processes to occur beginning with the photoreceptors and finishing with the neural process that triggers the motor response (O'Donell, Barraza & Colombo, 2010). Reaction times have commonly been used to quantify visual performance as a function of luminance contrast, size, and retinal luminance (Boyce & Rea, 1987; Rea & Ouellette, 1988). Significant improvements in visual performance have been reported with increases in target size, luminance contrast, and adaptation luminance.

The relationship between stimulus intensity, contrast, and reaction time has been investigated previously across different sensory modalities (vision, audition, cutaneous touch, taste and smell (Jaskowski & Sobieralska, 2004; Ludwig, Gilchrist & McSorley, 2004; White, Kerzel & Gegenfurtner, 2006). A consistent relationship between stimulus intensity and reaction time that is independent of the sensory modality under study has typically been reported. Piéron (1920) and Luce (1986) reported that the weaker the stimulus (such as a very faint light), the longer the reaction time. However, after the stimulus reaches a certain strength, reaction time becomes constant. Piéron's law (1952) mathematically describes these observed relationships as a hyperbolic decay function whereby as stimulus intensity increases, the behavioral reaction time decreases until a certain threshold is attained where reaction times plateau. This relationship has been demonstrated in a number of detection tasks that involve measurement of simple reaction time (SRT).

However, despite the above findings the effect of stimulus intensity on reaction time has been questioned in choice reaction time (CRT) tasks, especially when visual stimuli were used (Luce, 1986). Some authors have shown that CRT decreases as stimulus intensity increases (Lappin & Disch, 1972; Pachella & Fisher, 1969; Posner, 1986). Pins and Bonnet (1996) reported that the effect of intensity is comparable in CRT tasks as in SRT tasks. The authors suggested that the exponent of the Piéron function does not change with the complexity of the additional stages that are required between sensory processing and the decision process.

The strength of a sensory stimulation can affect the accuracy of response as well as its speed (Klein, 2001). The degradation of a stimulus either by reduced contrast sensitivity or intensity can affect performance by slowing sensory acquisition and encoding processes, in conjunction with typical interactions involving higher-order decision and processing stages (Cronin-Golomb, Gilmore, Neargarder, Morrison & Laudate, 2007). Previously, researchers have reported high stimulus strength to facilitate a decrease in response time and an increase in response accuracy. Conversely, low stimulus strength has been demonstrated to decrease response times and response accuracy (Palmer, Huk & Shadlen, 2005). The measurement of accuracy as a function of stimulus strength is known as psychometric functions these are of critical importance in the study of psychophysics (cf. Klein, 2001). In a series of experiments, Palmer et al. (2005) examined the effect of stimulus strength on the speed and accuracy of the perceptual decision. Of particular interest to the current paper was their first experiment which investigated the effect of motion strength on response time and accuracy. The results showed that both variables were dependent on motion strength; as motion strength increased response time decreased and accuracy increased. Numerous other researchers in psychophysics have identified that increasing stimulus strength enhances accuracy of response (cf. Klein, 2001). Furthermore, irrespective of stimulus intensity, more accurate responses have been associated with faster response times, and vice versa, in a number of choice paradigms including stroop-interference tasks (Kane & Engle, 2003; Wühr & Frings, 2008), various naming tasks (Duyck, Lagrou, Gevers & Fias, 2008; Roeflofs, 2006), and absolute identification (Kent & Lamberts, 2005; Lacouture & Marley, 1995, 2004; Petrov & Anderson, 2005).

In the present paper, two experiments are reported that examine the effect of stimulus strength on response time and response accuracy in a temporally-constrained, real-world, decision-making task. We examine the effect of increasing stimulus intensity of teammate's uniforms on the ability of soccer players to make rapid and accurate responses. In Experiment 1, it is predicted that increasing stimulus strength will encourage the use of the exogenous (stimulus-driven) control of attention; with research suggesting that performance is facilitated more rapidly by sensory cues rather than by cognitive cues (Posner & Cohen, 1984; Muller & Rabbitt, 1989). In the high stimulus intensity condition, we predict that individual's visual attention will be drawn to the teammate's uniforms more rapidly than in the control condition. We hypothesize that this earlier orientation of attention to pertinent environmental cues will expedite response times. These predictions are based on previous research were significant improvements in visual performance (as indexed by reaction time) have been reported as a function of increasing stimulus strength (Boyce & Rea, 1987; Rea & Ouellette, 1988). Moreover, numerous researchers have reported indicating that CRT decreases as stimulus intensity increases (Lappin & Disch, 1972; Pachella & Fisher, 1969; Posner, 1986). An increase in stimulus strength has also been reported to improve performance accuracy in a number of tasks (Klein, 2001) and decreased response times have often been associated with increased performance (Kent & Lamberts, 2005; Roeflofs, 2006). Consequently, we predict that in the high stimulus intensity condition individuals will demonstrate faster response times and increased response accuracy compared to the control condition.

Experiment 1

Materials & Methods

Participants

A sample of 8 male soccer players volunteered to take part. The participants were aged between 18-24 years and were currently playing at a professional level (Premier League

Academy and reserve players in the UK). The players had participated in the sport for a minimum of 10 years. All participants were right side dominant for everyday tasks and played in an offensive midfield position for the majority of their careers; at least 90% of games played in offensive positions. Participants provided informed consent and approval was gained via the local ethics committee.

Test Film

The test film was produced in conjunction with a professional soccer club. A total of 12 (6 defenders/6 attackers) 18-19 year old Academy players were recruited to simulate patterns of dynamic play. The filming was conducted on a standard size soccer field indoors with 6 defensive versus 6 offensive players who received detailed instruction and rehearsal in relation to the movement sequences that they were required to execute over a 2-day period. A panel of three UEFA (Union of European Football Associations) qualified soccer coaches determined the content and structure of the sequences of play. Only those sequences approved by all coaches as being representative of match action were include in the test film (90% of the representations were deemed appropriate). Altogether, twelve dynamic patterns of play were filmed under each of two different uniform conditions, namely control (low stimulus intensity: black) and experimental (high stimulus intensity: sequin). The low stimulus intensity uniform consisted of plain black shirt, shorts, and socks. The high stimulus intensity uniform design consisted of a black shirt and black shorts with a sequence of sequins sewn on to the apparel and plain black socks, as outlined in Figure 1. These 10 mm sequins were made of reflective silver material and covered a total of 20% of the shirt and shorts. The opposition team wore a kit consisting of a dark green shirt, shorts and socks. The total of 24 film sequences were recorded using a digital video camera (Canon DM-XM2 PAL, Tokyo, Japan) positioned in the middle of the pitch on the halfway line at eye level (1.7

m). The footage was then digitally edited using Adobe Premiere Pro CS4 software (Adobe Systems Incorporated, San Jose, CA, USA).

Procedure

The test film was front-projected onto a white wall (4 m x 3 m) in an attempt to provide a near life-size image. Participants stood 6 m away from the screen so that the film image subtended a visual angle of approximately 42° in the horizontal and 31° in the vertical direction. An automated, auditory "3, 2, 1" countdown was inserted on the video before each sequence to prepare the players for the start of the clip. The film commenced at the end of the countdown and players were asked to make a penetrative pass to one of the attacking players on screen (i.e., a pass that allowed the attacker an attempt on goal) quickly and accurately. In order to confirm that the ball was kicked towards the intended target player, each participant was asked to highlight verbally the player that they were passing the ball towards at the end of each clip. The average clip duration was 5 sec (range 4-6 sec) and the inter-trail interval was 20 sec. The entire session took about 20 mins to complete.

The ball was positioned between two infrared timing gates (Tag Heuer, Biel, Switzerland), which were activated when the ball was kicked. Players were positioned 1 m away from the ball. The film was occluded immediately after the timing gate was broken (i.e., after the ball was kicked) so as to prevent participants from gaining feedback, thereby reducing the potential for practice effects. No feedback was given in relation to performance accuracy. The players were tested individually and a sample of six practice trials was shown pre-experiment to help the participants familiarize themselves with the task. After familiarization, 24 film clips were presented. The clips were presented in a random order, but kept in the same order for each participant.

Dependent Measures and Analyses Methods

Two dependent measures were recorded:

Response time. This was measured from the start of the film sequence to the moment the timing gate beam was broken (i.e., the ball was kicked) (in ms).

Response accuracy. The accuracy of the decision made was evaluated with reference to the judgments of the panel of three UEFA coaches. A score of 1 was awarded if the decision was correct (a pass that would allow the attacker an attempt on goal), whereas no score was awarded if the incorrect pass was selected. The scores were converted to percentage values.

The two dependent measures were analyzed using separate paired samples *t* tests (low stimulus intensity/high stimulus intensity) to examine differences between uniform conditions. The effect sizes were calculated using Cohen's *d*. The alpha level for significance was set at 0.05. There were no violations of sphericity or normality.

Results

Response time. Participants recorded significantly longer response times while viewing clips involving the low stimulus intensity compared to high stimulus intensity uniform design, t (7) = -7.460, p < 0.01, d = 1.3. The mean response time values were approximately 300ms quicker in the high stimulus intensity (2288.68, SD = 217.55ms) compared to low stimulus intensity (M = 2597.58, SD = 253.93ms) uniform condition (see Figure 2).

Response accuracy. Participants had significantly higher response accuracy scores while viewing the high stimulus intensity compared to low stimulus intensity uniform design, t (7) = -3.052, p < 0.01, d = 1.23. While viewing the high stimulus intensity (M = 90.6, SD = 8.3%) uniform design participants were on average 13% more accurate compared to the clips involving the low stimulus intensity uniform design (M = 77.1, SD = 13.9%) (see Figure 2).

Experiment 2

Introduction

There have been significant theoretical advances in our understanding of the perceptual-cognitive skills underpinning anticipation and decision-making. However, much of the research has been criticised for using reductionist approaches that lack ecological validity which ultimately could lead to a degradation in the natural environment in which the actions usually occur. In a recent meta-analysis, Mann, Janelle, Williams and Ward (2007) highlighted the differences between data captured in laboratory-based studies and natural, *in situ* studies for a range of perceptual-cognitive skills. These data revealed that the method of stimulus presentation directly influenced both response accuracy and fixation duration. Stimulus presentations elicited large-to-moderate effects with significant increases in the magnitude of effects as the mode of stimulus presentation became progressively more representative of a real-world task (i.e., static, video, field). The authors were unable to assess the effect of presentation stimulus on response times due to the paucity of field-based research.

Many of these studies utilised a two-dimensional screen or a monitor. Such displays are considered to be deficient in what people naturally perceive in dimension and, in many experiments, size (Shim, Carlton, Chae & Chow, 2005). In many domains, such as sport or the military it is argued that film- or video-based stimulus presentations are not adequately representative of the dynamic nature of the environment (Abernethy, Burgess-Limerick & Parks, 1994). Furthermore, research employing these video-based simulations may not maintain ecological saliency on the perceptual dimension (Hoffman & Deffenbacher, 1993) or the essential characteristics of the task to be captured in a holistic manner. It is suggested that the use of film-based simulations significantly reduce the perceptual and sensory experience of the observer (Issacs & Finch, 1983).

This effect has been supported by Shim et al. (2005) who reported that a more detailed visual display facilitated performance for skilled individuals but not for novices.

Skilled and novice tennis players were required to anticipate the type of stroke and the direction in which the ball was hit under live, video and point-light presentation conditions. Findings showed that the experts obtained additional information in the live situation but not in the two projected visual conditions. These data suggest that the information needed to perceive subtle visual cues during an action may not be available from point-light or video displays. In a subsequent experiment, Shim et al. (2005) examined the ability to anticipate and respond to tennis serves in 'live hitter' and a ball machine conditions. The participants produced 25% faster response times in the 'live hitter' condition. These findings are consistent with those of Bruno and Cutting (1988) who suggested that when more visual information is made available, it is used in an additive fashion, but only if observers have experience with the task. In other studies, expert decision making has been reported to be facilitated under field conditions, suggesting that the more realistic the paradigm, the greater the measurement sensitivity (cf. Mann et al., 2007).

In the current experiment, we identify whether the effect of stimulus intensity on response accuracy and response time translates from the laboratory setting (Experiment 1) into the real-world environment (Experiment 2). The same hypotheses are presented as in Experiment 1. We predict that increases in stimulus intensity will decrease response time and increase response accuracy. Moreover, we hypothesise that the increased information available *in situ* compared to the laboratory setting in Experiment 1 will enable the participants to demonstrate shorter response times (Bruno & Cutting, 1988; Shim et al., 2005) and increased response accuracy (Mann et al., 2007; Shim et al., 2005).

Materials & Methods

Participants

A sample of 8 male soccer players volunteered to take part. The participants were aged between 18-24 years and were currently playing at a professional level (Premier League

Academy and reserve players). The players had participated in the sport for a minimum of 10 years. All participants were right foot dominant and played in an offensive midfield position for the majority of their careers. None of these participants had taken part in Experiment 1. Participants provided informed consent and approval was gained via the local ethics committee.

Procedure

The same twelve players used to make the test film in Experiment 1 were recruited to act out the live dynamic patterns of play. The same patterns of play and clothing wear conditions were used as in Experiment 1. Participants were instructed to wear occlusion goggles (PLATO Model P-1, Translucent Technologies, Canada), which prevent vision of the players, with participants positioned 1 m away from the ball. The glasses were intended to control the moment of visual exposure to the stimuli.

The players were located in a central position on the field of play mid-way between the half-way line and penalty box. The distance and viewing angle was selected to match as closely as possible those used in Experiment 1. All players were presented with a recorded “3, 2, 1” auditory countdown. On the signal “2” the actors started to simulate the pattern of play, whereas on the count of “1” the occlusion goggles become transparent so the participants were able to see the evolving play. Once the goggles were clear the players were asked to make a penetrative pass to one of the attacking players (i.e., a pass that allowed the attacker an attempt on goal) quickly and accurately. The goggles were used to occlude vision as soon as the time gate beam was activated. The same infrared timing gates as used in Experiment 1 were employed. The timer was initiated when the infrared beam was broken (i.e., the ball was kicked). The players were tested individually and a sample of six practice trials was shown pre-experiment to help the participants familiarize themselves with the task. After familiarization, a total of 24 trials were presented.

Dependent Measures and Analyses Methods

The same dependent measures were used in Experiment 2.

Results

Response time. Participants recorded no significant difference in response time across the two conditions, t (7) = -0.731, p < 0.04, d = 0.21. The mean response time values did not differ across the low stimulus intensity (M = 1332.67, M = +163.77ms) and high stimulus intensity (M = 1366.40, M = +153.49ms) uniform conditions (see Figure 2).

Response accuracy. Participants recorded significantly higher response accuracy scores in the high stimulus intensity compared to low stimulus intensity uniform design, t (7) = -3.274, p = 0.02, d = 1.14. In the high stimulus intensity (M = 88.5, SD = 9.9%) uniform design, participants demonstrated a 11% increase in performance accuracy compared to when viewing the clips in the low stimulus intensity uniform condition (M = 77.1, SD = 10.7%) (see Figure 2).

General Discussion

We examined the role of stimulus intensity on measures of response time and response accuracy in a dynamic, temporally-constrained environment. We were interested in investigating the effect of manipulating the stimulus strength of teammate's playing uniforms on the decision making performance of soccer players both in laboratory- and field-based experiments. Our novel approach increased the stimulus intensity of the playing uniforms worn by players through the use of reflective sequins in an effort to facilitate information pick-up and performance. In both experiments we predicted that in the high stimulus intensity condition the individual's visual attention will be drawn to the teammate's uniforms more rapidly than in the control condition; this earlier orientation of attention to pertinent environmental cues will expedite response times (Lappin & Disch, 1972; Posner, 1986; Rea & Ouellette, 1988). Furthermore, we predicted that in the high stimulus intensity condition individuals would demonstrate increased response accuracy compared to the control condition (Klein, 2001; Kent & Lamberts, 2005; Roeflofs, 2006). In Experiment 2, we also predicted that, as a result of the more detailed visual display and increased access to visual information, participants would demonstrate decreased response times (Bruno & Cutting, 1988; Shim et al., 2005) and increased response accuracy (Mann et al., 2007; Shim et al., 2005).

We report significant differences in both response time and response accuracy as a function of stimulus strength. In both experiments, participants recorded significantly higher response accuracy scores in the high stimulus intensity compared to the low stimulus intensity condition. In Experiment 1, response accuracy was 13.5% higher in the high stimulus intensity, compared to the low stimulus intensity condition; a comparable 11.4% increase was reported in Experiment 2. However, differences in response time, as a function of stimulus strength, were only reported in Experiment 1. In this laboratory-based condition, participants recorded response times that were approximately 300 ms faster in the high stimulus intensity compared to the low stimulus intensity condition. This latter effect did not translate into the field-based scenario employed in Experiment 2.

The results from Experiment 2 demonstrate that although response times did not differ between stimulus intensities the response accuracy increased as a function of increased stimulus strength. It is possible that the participant's attention was still directed to the stimulus earlier but took longer to process the information and execute a response. A possible explanation for this technique has been identified in a number of other studies. These studies report that decisions tend to be more accurate if participants are given longer exposure to a stimulus (Green & Luce, 1973; Wickelgren, 1977; Gold & Shadlen, 2000; Mateeff, Dimitrov, Genova, Likova, Stefanova & Hohnsbein, 2000) and when they are given the freedom to respond when ready participants will improve accuracy by taking more time (Luce, 1986).

This trade-off between accuracy and processing time suggests that participants may accumulate information to improve performance; the participants in the current experiment may be attempting to optimise processing time of sensory cues in order to increase response accuracy.

A large discrepancy was observed between the response time values reported in Experiments 1 and 2. In Experiment 2, participants recorded response times that were nearly 1000 ms faster than those in Experiment 1. We predicted that a more ecological valid condition would facilitate more rapid response times. The video-based design used in Experiment 1 reduced the ecological saliency and perceptual dimension that is inherent in the real-world scenario. Conversely, in Experiment 2 participants had access to additional visual information that was not present in Experiment 1. This supplementary information may have allowed participants to perceive subtle visual cues during the action sequences that may not be available from the video-based simulation. These results corroborate other findings where significant decreases in response time as a function of an increase in visual information have been reported (Shim et al., 2005) and numerous other studies which have identified differences in performance under laboratory- compared with field-based tasks (cf. Mann et al., 2007). Another theory is that the added contextual information available in Experiment 2 provided the participants with more motivation to execute the action at the exact moment necessary for accurate completion of the task in a real-world situation. Therefore, the response times were reduced and more comparable to those employed *in situ*. In the laboratory, this effect would be reduced by the lack of depth and contextual information accessible from the video image.

The fact that the high stimulus intensity uniform led to performance improvements without a decrease in the response time in the field-based test, suggests that it is not only the rapid detection of cues in the visual field that provided the performance advantage. Although the increased stimulus strength promoted exogenous attention control which allowed earlier stimulus detection, the increased stimulus strength may also have an effect on other processes. The increased stimulus strength can affect performance by facilitating sensory acquisition and encoding processes as well as their interaction with higher-order decision and processing stages (Cronin-Golomb et al., 2007). The increased stimulus strength may provide the participant with stronger target stimuli with which to process response options and set parameters for movement programming and effective action.

It appears that increasing the stimulus strength of the uniforms worn by teammates can promote the use of the exogenous orientation of attention. This affect can ultimately increase response accuracy in a dynamic, temporally-constrained environment, both in a laboratory and field setting. Findings provide support for previous work which has highlighted that the earlier orientation of attention to pertinent environmental cues expedites response times in CRT tasks (Lappin & Disch, 1972; Posner, 1986; Rea & Ouellette, 1988). These data also provide support for the role of stimulus intensity on response times (Piéron 1920; Luce, 1986) and extend the literature base into real-world tasks.

Our data add to contemporary research that has examined the role of stimulus intensity on response accuracy. Previously, researchers have identified that high stimulus strength can facilitate a decrease in response time and an increase in response accuracy (Klein, 2001; Palmer et al., 2005), yet the majority of research has been confined to laboratory-based methodologies. The current findings provide support for previous data captured in the laboratory and extend these concepts into more realistic test protocols. .

Our data have significant implications for applied practice. The ability to enhance accuracy by up to 13% and decrease response times by up to 300 ms simply by increasing the stimulus intensity of uniforms highlights the potential impact of uniform designs in sport. The use of a dynamic, field-based methodology with highly integrated perception-action coupling demonstrates the importance of uniform design in real-life, everyday activities. These findings could be extrapolated to other uniforms/equipment in other sports as well as in domains such as engineering and product design, media and advertising, along with military and law enforcement applications.

Perspective

This novel approach to investigating decision making and performance by manipulating uniform designs provides a valuable insight into the application of increasing stimulus strength to increase performance and paves the way for future research in the area. The data presented in the current paper extend the theory behind stimulus intensity and its relationship to stimulus-driven attentional control into an ecologically valid, dynamic task. The results demonstrate the effectiveness of stimulus strength as a method of heightening visual cues available in the visuomotor workspace, which facilitated significant improvements in response time and accuracy. These findings highlight the practical utility of using manipulations to playing uniform design to positively influence performance in sport and other fields of activity.

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Figure Captions

Figure 1. Uniform designs: a) Black uniform (low stimulus intensity); b) Sequin uniform (high stimulus intensity).

Figure 2. Response time and response accuracy between black and sequin uniform designs in both laboratory- and field-based experiments (mean±s.d). Legend: LB – Laboratory-based, black uniform; LS – laboratory-based, sequin uniform; FB – field-based, black uniform; FS – field-based, sequin uniform