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Fight without sight: The contribution of vision to judo performance

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ABSTRACT

Objective: Although vision is typically considered the predominant sense for guiding performance, there are sports for which other senses are believed to be as important, if not more important than vision. Accordingly, in Paralympic judo, athletes with different degrees of vision impairment (VI) compete together based on the assumption that vision does not influence judo performance, as long as judokas start the match with their grip in place. The aim of this research was to test this assumption.
Method: We conducted two studies. In the first we analysed data from two major recent VI judo competitions to compare the relative performance of blind and partially sighted athletes when competing against each other. In the second study, twenty-four able-sighted players competed in practice matches in sighted and blindfolded conditions.
Results: In Study 1, we demonstrated that blind judokas win far less medals in VI judo competitions than their partially sighted opponents. In study 2, a significant performance advantage was found for sighted judokas fighting against blindfolded opponents.
Conclusions: Vision enhances judo performance, even when judokas start the match with their grip in place. These findings suggest that it would be desirable to take measures to make VI judo competition fairer to those who are most severely impaired.

1. Introduction

Research into the perceptual expertise of athletes has been mostly limited to vision (Mann, Williams, Ward, & Janelle, 2007), and this may fail to adequately capture the multisensory expertise of both able-sighted as well as visually impaired athletes. Indeed, vision is traditionally considered crucial to human perception and often dominates over other senses (Colavita, 1974; Posner, Nissen, & Klein, 1976). Yet there are sports in which other senses may be as important, if not more important than vision. For example, in sports where physical contact between players is allowed, athletes may also use haptics and kinesthesis to anticipate the action intentions of the opponent and to guide their action. The level of sanctioned physical contact between opponents can be used as a way to categorize sports, ranging from those without contact (e.g. tennis, volleyball), to incidental contact (e.g. soccer, basketball), through to full-contact sports (e.g. rugby, karate). In some full-contact sports, such as wrestling or judo, athletes remain in contact with each other throughout a large part of the game. Because of the constant access to haptic and kinaesthetic information, these sports might even be performed quite adequately without vision. Judo for instance is one the most popular Paralympic sports for athletes with a vision impairment (VI). The rules in Paralympic or VI judo are largely the same as in the Olympic or able-sighted version of the sport, with one important exception. In able-sighted judo, competitors start a few meters apart and at the start of the match, athletes must approach each other and first fight for a favourable grip on their opponent before they can unbalance and throw them. In VI judo however, the two fighters are required to take hold of each other before the start of the match, avoiding the need to (visually) search for a grip, ensuring they can immediately rely on haptic and kinaesthetic information from the commencement of the contest.

To ensure fairer competition, in most VI sports partially sighted athletes either compete separately from athletes who are fully blind (e.g., VI swimming), or in some cases all athletes can be required to wear blindfolds to ensure that all athletes are effectively 'blind' during competition (e.g., VI soccer and goalball). However, blindfolds are generally disapproved of by VI athletes because they prevent an athlete's ability to make use of their limited remaining

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vision (Ravensbergen, Mann, & Kamper, 2016). In VI judo, blind and partially sighted athletes compete against each other in the same class, and without blindfolds. This system has been designed on the assumption that the magnitude of vision impairment should not affect performance in VI judo, as long as each match starts with the judokas taking grip of their opponent.[1] This notion suggests that judokas when in contact can fully rely on other sensory information (presumably haptic or kinaesthetic) and do not benefit from additional visual information. Consequently, a VI judoka with more severe vision impairment is assumed not to be at a disadvantage when fighting an opponent with less vision impairment.

There is evidence to demonstrate a vital role for vision in judo, though this is limited to when fighting to obtain a grip on the opponent. Piras, Pierantozzi, and Squatrito (2014) reported expertise effects in visual search behaviour for able-sighted judokas during the exchange of first grips. They found that experts fixate their gaze more on the chest and face of their opponent, whereas the gaze of novices is directed more towards their opponent's hands and/or sleeve. These results correspond with similar research on visual search behaviour and expertise in other sports, where the gaze of experts is usually found to be directed more at the centre of the opponent's body than that of novices (Mann et al., 2007). While these findings are informative in supporting the assumptions made about the role of vision in obtaining a grip on the opponent, little is known about the visual demands of judo after a grip is obtained.

Considering that human perception is largely multisensory (Ernst & Bülthoff, 2004), the notion that vision would not contribute to judo performance even after the grip is in place seems rather surprising. In our exploration of the world we do not use sight in isolation from hearing, smell or touch; across a wide range of perceptual tasks, research has shown that human perception becomes more accurate and robust through simultaneous information pickup by different senses (Alais & Burr, 2004; Lalanne & Lorenceau, 2004; Stein & Meredith, 1993). The benefits of multisensory perception are commonly explained as a process of uncertainty reduction. By combing independently sampled bits of sensory information, a more reliable percept of the environment can be formed (Ernst & Banks, 2002). These ideas fit well with the specificity of practice hypothesis (Proteau, Marteniuk, & Lévesque, 1992) which states that performers built expertise in those sensory conditions under which they practice.

Also within sports, there are clear performance benefits through multisensory perception, or rather, performance decrements are found when certain sensory information is taken away. For instance, Takeuchi (1993) found that experienced tennis players performed worse in a practice match while wearing earplugs, depriving them of auditory information. Heinen, Koschnick, Schmidt-Maaß, and Vinken (2014) let gymnasts synchronise to a model gymnast whom they could either see (vision-only), hear (audition-only) or both. They found that synchronicity was reached in fewer attempts in the vision-only condition than it was in the audition-only condition, but a combination of visual and auditory information yielded the best results. Gray (2009) found that vision dominated the performance effects possible from audition or touch in baseball batting tasks, but again the best performance was obtained when information from vision, audition and touch were all available simultaneously.

The aim of this project was to examine whether vision contributes to performance when in contact with an opponent in a combat sport. Based on the literature on multi-sensory perception, we expected that combat athletes would benefit from access to visual information. To test this hypothesis we conducted two studies. In the first we analysed data from two major recent VI judo competitions to compare the relative performance of blind and partially sighted athletes when competing against each other. In the second study, able-sighted players competed in practice matches in sighted and blindfolded conditions. We hypothesised that in both studies sighted judokas would be able to exploit the additional visual information to provide an advantage over their blind or blindfolded opponents.

2. Study 1

In VI judo, although partially sighted and blind athletes compete together, all athletes must still undergo 'classification' according to the rules of the International Blind Sports Federation (IBSA). During classification, vision is tested to determine whether the athlete meets the *minimum impairment criteria* to compete in competition, and to allocate a *sport class* to the athlete (see Table 1 for a description of the criteria). In this first study we examined the medal distribution between partially sighted (class B3 and B2) and essentially blind (class B1[2]) competitors in two recent major VI judo competitions.

2.1. Method

Data from the 2014 IBSA Judo World Championships (USA) and the 2015 IBSA World Games (Korea) were retrieved from the IBSA website.[3] For each competitor the sport class (B3, B2 or B1) and the final result (medal or no medal) were collected. Medal distributions were compared through a Chi square test of independence. If significant differences were found, post-hoc testing was performed by additional Chi square tests with Bonferroni corrections comparing the medal performance of each class against the other two classes combined.

2.2. Results

Results are shown in Table 2. In both events over 200 judokas participated across thirteen weight categories (7 male and 6 female categories), winning a total of 52 medals. Although in both tournaments around 20% of the competitors were blind (class B1), this group of athletes collected only 2% of the medals in the 2014 tournament, and 8% in the 2015 tournament. Chi square tests confirmed that medals were not equally distributed between the three sport classes (2014: $\chi^2(2) = 15.56$, $p < 0.001$; 2015: $\chi^2(2) = 7.59$, $p = 0.02$). Collapsing the data into 2×2 contingency tables, in both events the B1 judokas won significantly less medals than expected (2014: $\chi^2(1) = 14.37$, $p < 0.001$; 2015: $\chi^2(1) = 7.55$, $p = 0.01$). In 2014, the number of medals won by B3 judokas seemed significantly higher than expected ($\chi^2(1) = 5.58$, $p = 0.02$), but not in 2015 ($\chi^2(1) = 0.63$, $p = 0.43$).

2.3. Discussion

The aim of this initial study was to compare the performance of partially sighted and blind athletes in major international VI

[1] In fact, until recently this was explicitly stated at the British Paralympic website (http://paralympics.org.uk/paralympicsports/judo) until it was removed in 2016. We are not aware of the reasons for this removal, but do notice that it was not accompanied by any change in classification regulations of VI judo.

[2] Athletes with some limited vision (typically only the perception of light) are also eligible to compete in the B1 class, though most are fully blind. Here we consider this class to be functionally 'blind'.

[3] http://www.ibsasport.org/sports/judo/results/.

Table 1
Classification criteria for visually impaired athletes according to IBSA regulations. Athletes can be classified based on tests of visual acuity, a measure of the sharpness or clarity of vision, or visual field, a measure of the area of peripheral vision with which an individual can see (i.e., without moving their eyes). Only one of the two criteria (visual acuity or visual field) needs to be met in order to be allocated to a sport class.

Class	Visual acuity (LogMAR)	Visual field (radius)	Description
B3	1.0 to 1.4	Less than 20 degrees	Limited visual acuity and/or visual field in both eyes.
B2	1.5 to 2.6	Less than 5 degrees	Severely limited visual acuity and/or visual field in both eyes.
B1	Poorer than 2.6	Cannot be B1 with only loss of visual field	An athlete can distinguish only light from dark, or is not able to perceive light.

Table 2
Number of participants and medals for VI judo athletes at the IBSA Judo World Championships 2014 and 2015.

	2014			2015		
Class	Competitors	Medals expected	Medals obtained	Competitors	Medals expected	Medals obtained
B3	73 (33%)	17 (33%)	24 (46%)	68 (32%)	17 (33%)	19 (37%)
B2	103 (47%)	24 (46%)	27 (52%)	99 (47%)	24 (46%)	29 (56%)
B1	45 (20%)	11 (21%)	1 (2%)	45 (21%)	11 (21%)	4 (8%)
Total	*220 (100%)*	*52 (100%)*	*52 (100%)*	*212 (100%)*	*52 (100%)*	*52 (100%)*

judo competitions. We revealed that blind athletes won significantly less medals during these events than would be expected based on participation numbers. This outcome is in contrast to the assumption that the degree of vision impairment would not impact performance, and therefore challenges the assumption that blind athletes can compete equitably with partially sighted opponents in VI judo. This finding supports our hypothesis that judokas with limited vision experience a benefit during VI judo competition.

The disadvantage for the blind athletes might not necessarily be attributed to disadvantages in performance during competition, but could also extent to limitations in the ability to prepare for competition. Blind athletes might be limited in their access to training because they might depend on a guide to take them to training facilities. They might also be adversely affected in their ability to acquire or improve skills during training because they cannot model their movements on others they see. These disadvantages in the quantity and quality of training could explain the lesser performance of the blind judokas during competition (rather than demonstrating a vital role for vision). To disentangle these two possible explanations, we conducted an experimental study where we compared the judo performance of able-sighted athletes who competed both with and without the benefit of vision.

3. Study 2

The aim of study 2 was to examine the extent to which able-sighted judokas benefit from vision when in contact with an opponent during a judo match. To control for possible impairments in skill acquisition commensurate with increases in vision impairment, we compared the performance of judokas who competed both when fully sighted, and when blindfolded.

3.1. Method

3.1.1. Participants

A specifically convened friendly judo tournament served as the experimental setting. Twenty-four skilled judo players (7 female, age: M ± SD = 13.5 ± 1.8 years, weight: M ± SD = 46.3 ± 8.7 kg, training volume: M ± SD = 5.1 ± 1.2 h of judo training per week), competing at the national level in their age group, accepted an invitation to participate. The local ethics committee approved the study, and participants and one parent/guardian provided written informed consent to take part.

3.1.2. Apparatus and materials

The tournament was held at a dojo (a training place for martial arts) that housed two competition areas (5 × 5m) so that two matches could be held simultaneously. Video footage of all matches were recorded each using two video cameras (Kodak PlaySport) positioned on opposite corners of the mat. This design ensured that participants were always visible by at least one of the two cameras during competition. Eyeshades (opaque grey colour, 8.5 cm in height, commercially available, adjustable to head size) were used to blindfold the participants when necessary.

3.1.3. Procedures

Participants were placed into groups of three so that they would fight each opponent in their own group twice (a total of four fights or 'matches' per participant). Groups were formed to promote fair competition by matching, as closely as possible, the age, gender and weight category of the participants in each group, according to the classification of regular competition. In case we had to deviate from the regular age and weight categories, the coach was consulted to form groups of participants that were judged to be reasonably equitable to compete against each other. This resulted in two of the groups having both males and females, six groups having participants who would normally compete in a different weight category, and two groups with participants who would normally compete in a different age category. None of the participants were required to compete against others who would normally differ by more than one consecutive age group or weight category.

In each match, one of the two judokas was blindfolded. Participants thus fought each of their opponents both when sighted (with the opponent blindfolded) and when blindfolded (with the opponent sighted). Matches were adjudicated by a national level judo referee and followed regular judo rules except for several modifications. First, matches started with the grip of the opponent in place, in accordance with the official regulations of VI judo. Second, matches lasted three minutes, and the clock was paused during each break to ensure three minutes of actual contest time in each match. Third, to standardise the time of all fights, the match did not end if a competitor scored a full point

(ippon) as would happen during regular judo.[4] Rather, competition continued until the completion of the three minutes. Fourth, to ensure that the time spent in standing fight was equal in all matches, ground fighting was excluded. Instead, after each successful or failed throw attempt the referee paused the match. Every time the referee paused the match (e.g., when one of the judokas fell to the ground, or when they walked out of the competition area), participants were required to return to their starting positions and to grip each other again before continuing the game.

Pilot testing was conducted to assess the feasibility of our approach. During pilot testing we found significant effects of blindfolding on judo performance. However these effects seemed to occur primarily within the first half of the fights. One possible explanation for these findings would be that the sighted player took a quick lead in the first half of the fight and tactically defended this lead throughout the remainder of the match. To motivate players to keep scoring throughout the whole match instead of tactically defending a lead, participants were instructed that the player who scored the most points over all four matches would be declared the winner of the tournament and would be awarded a trophy.

An alternative explanation for our pilot study results would be that blindfolded participants first had to get used to fighting without sight within the first half of the match, but were no longer at a disadvantage in the second half when they were sufficiently habituated. To minimise the effect of habituation on match outcome, several precautions were taken to ensure the participants became accustomed to fighting blindfolded. Approximately half an hour before the start of the tournament, participants followed a warm-up protocol which incorporated the use of regular judo exercises with closed eyes and blindfolds. In addition, participants were blindfolded one minute before the start of their match and players took part in a minute of practice fighting in which no score was kept so that the blindfolded athlete could become accustomed to fighting without vision. To assess differences in physical load in the sighted and blindfolded conditions, ratings of perceived exertion (RPE) were collected for each participant after each fight using a Borg CR10 scale (Borg, 1998).

3.1.4. Data analysis

To verify the decisions of the referee, video footage were analysed by one of the authors who is an experienced judo coach and holds a black belt in judo. In case of doubt about a refereeing decision, the video footage was shown to the two national level referees again to reach agreement. For each match, both the number of successful *throws* (i.e. the number of throws resulting in a score) as well as their total value in *points* (yuko = 5 points, waza-ari = 7 points, ippon = 10 points) were collected for each judoka. To verify there were no effects of habituation, these measures of performance were collected separately for the first and the second half of a fight. Because of the counterbalanced nature of the design, where each participant competed against the same opponent both with and without a blindfold, performance measures could be compared for each competitor across the different visual conditions (by averaging performance scores across the two fights where the participant was sighted, and the two fights where blindfolded). Performance was compared using a 2 (Vision: sighted, blindfolded) by 2 (Half: first, second) analysis of variance with repeated measures on both factors. Mean RPE scores for each participant were compared in the sighted and the blindfolded condition using a Wilcoxon signed-rank test.

3.2. Results

Twenty-four competitors were scheduled to take part in four matches each, totalling 48 scheduled matches. As is the nature of combat sports (Drew et al., 2015; Pocecco et al., 2013), injuries and drop-out resulted in the completion of 40 matches, with 6 of 24 participants withdrawing due to injury or choosing to discontinue. To maintain a balanced design whereby participants competed against each other in a counterbalanced fashion, we excluded any matches where we did not have the corresponding 'return' bout (e.g., where we had Participant A blindfolded vs Participant B with vision, but not Participant A with vision vs. Participant B blindfolded). As a result, 32 matches from a total of 21 participants ($M_{age} \pm SD = 14.0 \pm 1.8$ years; 5 female) were included in our final analysis.

The results (Fig. 1) showed a significant main effect of vision on the number of successful throws ($F(1,20) = 12.86$, $p = 0.002$, $\eta_p^2 = 0.39$) as well as on the total amount of points ($F(1,20) = 8.99$, $p = 0.007$, $\eta_p^2 = 0.31$). In the blindfolded condition, participants

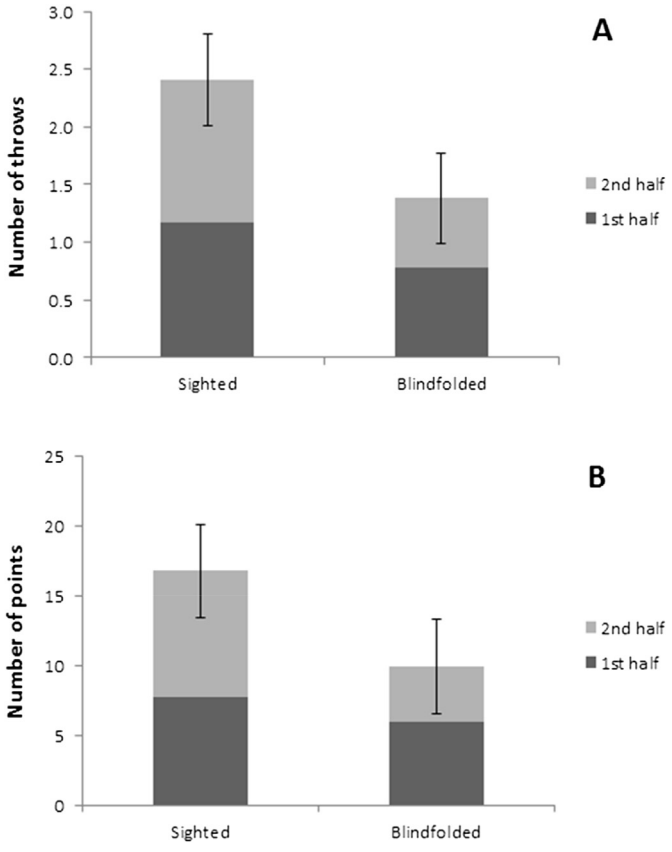

Fig. 1. Number of (A) successful throws made and (B) points scored by judokas in the sighted (against a blindfolded opponent) and blindfolded (against a sighted opponent) conditions. Error bars show within-participant 95% confidence intervals calculated according to the Cousineau-Morey method (Morey, 2008).

[4] A successful throw in judo can result in a low score (yuko, 5 points), medium score (waza-ari, 7 points) or a high score (ippon, 10 points). After each successful throw the score is verbally announced by the referee. As of January 2017, the point system in judo has changed so that the lowest score (yuko) has disappeared, and a throw can now only be awarded a medium (waza-ari) or high score (ippon). However, these rules were not yet in place when our experiment was conducted and therefore the old rules were applied both in the experiment as in the analysis of results. Since the main goal for our participants was to score as many points as possible, it is unlikely that the behaviour of participants would have been fundamentally different under the new rules.

performed less scoring throws, and scored less points, when compared to the sighted condition (throws, M ± SD = 1.4 ± 1.6 vs. 2.4 ± 2.3; points, M ± SD = 10.0 ± 12.1 vs. 16.8 ± 17.7). Performance did not differ across the two halves of the fight (throws, $F(1,20) = 0.14$, $p = 0.71$, $\eta_p^2 = 0.01$; points, $F(1,20) = 0.15$, $p = 0.71$, $\eta_p^2 = 0.01$) and the effect of vision did not differ across the two halves (no interaction effects: throws, $F(1,20) = 0.59$, $p = 0.45$, $\eta_p^2 = 0.03$; points: $F(1,20) = 0.96$, $p = 0.34$, $\eta_p^2 = 0.05$). RPE was marginally lower in the sighted (M = 5.5, SD = 1.3) compared to the blindfolded condition (M = 6.2, SD = 1.5), with the result of the Wilcoxon signed rank test bordering on significance ($Z = -1.96$; $p = 0.05$, $r = 0.31$).

3.3. Discussion

The results of Study 2 confirmed that the deprivation of visual information does considerably decrease performance when in contact in judo. Although judokas without vision were still able to compete with their opponents in matches in a three-minute fight that started with the grip in place (blinded participants still did complete successful throws), performance in the blindfolded condition was considerably worse and perceived exertion slightly higher when compared to the sighted condition. Since no differences in the first and second half of the fight were found, these findings cannot easily be attributed to blindfolded participants being insufficiently habituated or motivated to keep fighting and scoring until the end of each match.

Still it would be fair to argue that the participants in our study were fighting without any long-term adaptation to vision impairment and therefore that their performance might not represent that of a habituated B1 athlete. However, in examining the impact of vision impairment on performance, we are less interested in the performance of a VI athlete who has trained hard to habituate and compensate for their impairment, but rather we are interested in the 'raw' impact of impairment before habituation has occurred. If a VI athlete has trained hard to compensate for their impairment, then they should not be penalised for this compensation by being placed into a different class, or worse still, deemed ineligible to compete. Instead, they should be able to capitalise on the benefit of their training to defeat others who are less trained but have a similar level of impairment. It is for this reason that the simulation approach we have adopted in this study provides a unique insight into the 'raw' impact of impairment before there is a chance for long term adaptations to alter performance.

It should be noted that the results of the current study might not be readily generalised to the practice of VI judo competition. We adopted a slightly different competition format, excluding ground fight and occasionally grouping athletes of different weight or age categories together. Furthermore, the difference in visual ability between our participants (i.e. full vision vs. no vision) is much larger than allowed for in actual VI judo competition (i.e. limited vision vs. no vision). Future research might overcome this limitation by simulating different levels of vision impairment artificially.

4. General discussion

The aim of this project was to examine whether vision contributes to performance when in contact with an opponent in a combat sport. In Study 1 we demonstrated that blind judokas win far less medals in VI judo competitions than their partially sighted opponents, supporting the notion that vision contributes to performance. To control for possible long term effects of vision impairment on skill acquisition during training, in Study 2 we compared the performance of sighted judo athletes fighting when in contact both with and without a blindfold. A clear advantage was found for a sighted judoka fighting against a blindfolded opponent. We therefore conclude that vision contributes to judo performance not only during the exchange of the first grip (Piras et al., 2014), but also once the grip is in place and the athletes are in contact.

An important point to make on the basis of our findings is that, although the judokas performed worse when blindfolded, they were not completely helpless. They were still able to throw their sighted opponents on average 1.4 times and scored 10.0 points per match. Likewise, blind judo players are in some cases capable of defeating partially sighted opponents to win Paralympic medals. In the absence of vision, evidently judokas can rely on haptic and kinaesthetic information obtained through their grip on the opponent's jacket to support their performance. However, fighting with access to visual information clearly leads to superior performance. These results are consistent with research which demonstrates that multisensory information makes perception more accurate and robust than when it is picked up using only one sense (Lalanne & Lorenceau, 2004).

Multisensory perception is often explained as a process of maximum likelihood estimation. That is, based on dominant cognitive approaches, a common explanation for the benefits of multisensory perception is that since information or sensory cues are impoverished and probabilistic in nature, perception becomes more accurate when different, independent cues (such as haptic and visual) can be integrated and combined based on prior knowledge and assumptions (Landy, Banks, & Knill, 2012). For example, models of maximum likelihood estimation through Bayesian inference have been used to accurately predict human behaviour in experimental settings, specifically in the area of visual-haptic integration (Alais & Burr, 2004; Ernst & Banks, 2002). Proponents of this view would argue that a judoka uses the tactile and kinaesthetic senses to pick up noisy cues from his opponent (such as their feet position, pulling and pushing force, or direction of movement). When additional, independent cues can be picked up through vision and combined with haptic and kinaesthetic cues, uncertainty decreases and a more reliable percept is built about the opponent's action or intentions on which the judoka can decide his next move.

Recent advances in both neuroscience and psychology, however, provide an alternative to this cognitive approach to multisensory perception. They indicate that the brain does not distinguish input from different senses as long as they provide us with the same relevant information (Camponogara, Rodger, Craig, & Cesari, 2017; Rosenblum, Dias, & Dorsi, 2017). Information is in essence of task-specific, amodal higher-order invariant rather than constructed from multiple low-order sensory-specific cues. This conceptualisation seems to correspond better to an ecological approach to perception and action. Rather than building up a complex percept from the integration of simple impoverished stimuli into an internal representation, ecological psychologists argue that the environment in all its complexity can be directly perceived and acted upon by the observer because information across different energy arrays is already meaningful (Michaels & Carello, 1981). From this perspective, it may be argued that the specific information required for optimal judo performance is carried by a combination of vision and touch, and cannot be picked up through either of these senses alone.

An important aspect of the ecological approach is that perception is active. Active exploration is thought to co-structure the different energy patterns, which grants the specification of action opportunities or *affordances* (J. J. Gibson, 1979; Michael Turvey & Fonseca, 2014). James J. Gibson (1962), as well as others (e.g., M. T. Turvey, 1996), have shown how, in the absence of vision, humans can perceive object properties (such as size, shape or texture) by wielding the objects in their hands, that is, through active

exploration. Accordingly, judokas (sighted or not) may explore their environment through active touch, by pushing and pulling their opponent around the mat. However unlike the static objects typically studied in research on active touch, exploratory pushing and pulling in judo directly affects the behaviour of the opponent, who will resist, push and pull back, or perhaps passively comply, thereby creating new opportunities for action, whilst eliminating others. Affordance perception in judo thus emphasises an interaction with others, rather than acting upon objects. Further research on affordance perception in judo might therefore not only be of practical use to (VI) judo athletes and coaches, but might also be generalized to the domain of social affordances, showing that active touch (and vision) can provide a basis not only for the perception of object properties, but also for the understanding of the intentions of others in (social) interactions (Valenti & Gold, 1991).

Whether a cognitive or an ecological framework is preferred, we argue that the literature on perceptual expertise is largely biased towards a unimodal approach and mainly concentrated on vision. Visual skills of expert performers have been studied extensively in sports (Mann et al., 2007), as well as in other contexts such as driving (Hills, 1980). Expertise effects have been reported for other sensory modalities as well. Musicians for example excel in auditory perceptual skills (Koelsch, Schröger, & Tervaniemi, 1999), wine judges are known for their refined olfactory perception (Parr, Heatherbell, & White, 2002) and expert sailors distinguish themselves from beginners by their level of cutaneous wind perception (Pluijms, Cañal-Bruland, Bergmann Tiest, Mulder, & Savelsbergh, 2015). However to truly understand the vast perceptual capabilities as well as limitations of both the able-bodied and the sensory impaired, researchers will need to acknowledge the multisensory nature of perception and study how optimal combinations of sensory information facilitate expert performance.

5. Practical implications

The assumption that vision plays no role in judo as long as the athletes have a grip on each other provides the basis on which the current VI judo classification system has been built. The current findings question this assumption. Our experimental study suggests that the current classification system used in VI judo may inadvertently be disadvantageous to blind judokas who compete against partially sighted opponents, and hence, it appears desirable to take measures that would make competition fairer to those who are most severely impaired. One solution could be to require all VI judokas to wear blindfolds in competition, as is required in other VI sports such as soccer or goalball. Ravensbergen et al. (2016) reported strong consensus amongst a panel of experts in VI sport that it would generally be inappropriate to use blindfolds to further impair athletes who are already limited in their visual abilities. However, a majority of the panel also argued that there may be situations in which it might be appropriate for athletes to wear blindfolds. Given the experimental results presented in this paper, it may be viable to consider whether it would be appropriate for all VI judokas to wear blindfolds during competition. This approach would ensure that all athletes compete using the same level of vision (i.e., none), but it does introduce other potentially complicating factors including the potential advantage afforded to those with some vision who can train with the benefit of vision, or the potential benefit to those with no vision who are able to compete in their habitual visual state. An alternative solution would be to split competition into different classes based on the degree of vision impairment, such as in VI athletics or swimming. Further research would be required to determine how many classes would be needed and how these classes should be composed, i.e. what the cut-off points between these classes should be. Practicalities would have to be considered here as well; medal events are generally limited for Paralympic sports and VI judo is already split by gender and weight into thirteen different categories. Another point of consideration in the discussion on equal chances for all competitors, which goes beyond the scope of the current work, would be the impact of hearing impairment on performance in VI judo. Although hearing impairment is not an eligible impairment within Paralympic sports, VI judo holds explicit regulations for judokas who are both visually impaired and deaf. Referee decisions are signalled to these athletes tactually by tracing signs on their hand (to indicate points and penalties awarded) or a tap on their back (to indicate start and halt signals). A revision of the current classification system for VI judo would thus have to take into account both empirical findings as well as practical considerations in order to fulfil the Paralympic aim to “minimise the impact of impairment on the outcome of competition” (Tweedy & Vanlandewijck, 2011).

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References

Alais, D., & Burr, D. (2004). The ventriloquist effect results from near-optimal bimodal integration. *Current Biology, 14*(3), 257–262. http://dx.doi.org/10.1016/j.cub.2004.01.029.

Borg, G. (1998). *Borg's perceived exertion and pain scales*. Champaign, IL: Human Kinetics.

Camponogara, I., Rodger, M., Craig, C., & Cesari, P. (2017). Expert players accurately detect an opponent's movement intentions through sound alone. *Journal of Experimental Psychology: Human Perception and Performance, 43*(2), 348–359. http://dx.doi.org/10.1037/xhp0000316.

Colavita, F. B. (1974). Human sensory dominance. *Perception & Psychophysics, 16*(2), 409–412. http://dx.doi.org/10.3758/bf03203962.

Drew, M. K., Giles, L. S., Nasser, A. M., Scullion, P., Humberstone, C. E., Reale, R., et al. (2015). Injuries sustained during an international judo training camp. In *American College of Sports Medicine conference* (San Diego, California, USA).

Ernst, M. O., & Banks, M. S. (2002). Humans integrate visual and haptic information in a statistically optimal fashion. *Nature, 415*(6870), 429–433.

Ernst, M. O., & Bülthoff, H. H. (2004). Merging the senses into a robust percept. *Trends in Cognitive Sciences, 8*(4), 162–169. http://dx.doi.org/10.1016/j.tics.2004.02.002.

Gibson, J. J. (1962). Observations on active touch. *Psychological Review, 69*(6), 477–491. http://dx.doi.org/10.1037/h0046962.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston: Houghton Mifflin.

Gray, R. (2009). How do batters use visual, auditory, and tactile information about the success of a baseball swing? *Research Quarterly for Exercise and Sport, 80*(3), 491–501. http://dx.doi.org/10.1080/02701367.2009.10599587.

Heinen, T., Koschnick, J., Schmidt-Maaß, D., & Vinken, P. M. (2014). Gymnasts utilize visual and auditory information for behavioural synchronization in trampolining. *Biology of Sport, 31*(3), 223–226. http://dx.doi.org/10.5604/20831862.1111850.

Hills, B. L. (1980). Vision, visibility, and perception in driving. *Perception, 9*(2), 183–216. http://dx.doi.org/10.1068/p090183.

Koelsch, S., Schröger, E., & Tervaniemi, M. (1999). Superior pre-attentive auditory processing in musicians. *NeuroReport, 10*(6), 1309–1313.

Lalanne, C., & Lorenceau, J. (2004). Crossmodal integration for perception and action. *Journal of Physiology-Paris, 98*(1), 265–279. http://dx.doi.org/10.1016/j.jphysparis.2004.06.001.

Landy, M. S., Banks, M. S., & Knill, D. C. (2012). Ideal-observer models of cue integration. In J. Trommershäuser, K. P. Kording, & M. S. Landy (Eds.), *Sensory cue integration* (pp. 5–29). Oxford University Press.

Mann, D. T. Y., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport and Exercise Psychology, 29*(4), 457–478. http://dx.doi.org/10.1123/jsep.29.4.457.

Michaels, C. F., & Carello, C. (1981). *Direct perception*. Englewood Cliffs, NJ: Prentice-Hall.

Morey, R. D. (2008). Confidence intervals from normalized data: A correction to cousineau (2005). *Tutorials in Quantitative Methods for Psychology, 4*, 61–64.

Parr, W. V., Heatherbell, D., & White, K. G. (2002). Demystifying wine expertise:

Olfactory threshold, perceptual skill and semantic memory in expert and novice wine judges. *Chemical Senses, 27*(8), 747–755. http://dx.doi.org/10.1093/chemse/27.8.747.

Piras, A., Pierantozzi, E., & Squatrito, S. (2014). Visual search strategy in judo fighters during the execution of the first grip. *International Journal of Sports Science & Coaching, 9*(1), 185–198. http://dx.doi.org/10.1260/1747-9541.9.1.185.

Pluijms, J. P., Cañal-Bruland, R., Bergmann Tiest, W. M., Mulder, F. A., & Savelsbergh, G. J. P. (2015). Expertise effects in cutaneous wind perception. *Attention, Perception, & Psychophysics, 77*(6), 2121–2133. http://dx.doi.org/10.3758/s13414-015-0893-6.

Pocecco, E., Ruedl, G., Stankovic, N., Sterkowicz, S., Del Vecchio, F. B., Gutiérrez-García, C., et al. (2013). Injuries in judo: A systematic literature review including suggestions for prevention. *British Journal of Sports Medicine, 47*(18), 1139.

Posner, M. I., Nissen, M. J., & Klein, R. M. (1976). Visual dominance: An information-processing account of its origins and significance. *Psychological Review, 83*(2), 157–171. http://dx.doi.org/10.1037/0033-295X.83.2.157.

Proteau, L., Marteniuk, R. G., & Lévesque, L. (1992). A sensorimotor basis for motor learning: Evidence indicating specificity of practice. *The Quarterly Journal of Experimental Psychology Section A, 44*(3), 557–575. http://dx.doi.org/10.1080/14640749208401298.

Ravensbergen, H. J. C., Mann, D. L., & Kamper, S. J. (2016). Expert consensus statement to guide the evidence-based classification of paralympic athletes with vision impairment: A delphi study. *British Journal of Sports Medicine, 50*(7), 386–391. http://dx.doi.org/10.1136/bjsports-2015-095434.

Rosenblum, L. D., Dias, J. W., & Dorsi, J. (2017). The supramodal brain: Implications for auditory perception. *Journal of Cognitive Psychology, 29*(1), 65–87. http://dx.doi.org/10.1080/20445911.2016.1181691.

Stein, B. E., & Meredith, M. A. (1993). *The merging of the senses*. Cambridge, MA, US: The MIT Press.

Takeuchi, T. (1993). Auditory information in playing tennis. *Perceptual and Motor Skills, 76*(3_suppl), 1323–1328. http://dx.doi.org/10.2466/pms.1993.76.3c.1323.

Turvey, M. T. (1996). Dynamic touch. *American Psychologist, 51*(11), 1134–1152. http://dx.doi.org/10.1037/0003-066X.51.11.1134.

Turvey, M. T., & Fonseca, S. T. (2014). The medium of haptic perception: A tensegrity hypothesis. *Journal of Motor Behavior, 46*(3), 143–187. http://dx.doi.org/10.1080/00222895.2013.798252.

Tweedy, S. M., & Vanlandewijck, Y. C. (2011). International Paralympic Committee position stand—background and scientific principles of classification in Paralympic sport. *British Journal of Sports Medicine, 45*(4), 259.

Valenti, S. S., & Gold, J. M. M. (1991). Social affordances and interaction I: Introduction. *Ecological Psychology, 3*(2), 77–98. http://dx.doi.org/10.1207/s15326969eco0302_2.