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No effect of blue on winning contests in judo

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A study by Rowe *et al.* reported a winning bias for judo athletes wearing a blue outfit relative to those wearing a white one during the 2004 Olympics. It was suggested that blue is associated with a higher likelihood of winning through differential effects of colour on opponent visibility and/or an intimidating effect on the opponent. However, we argue that there is no colour effect on winning in judo. We show that alternative factors, namely allocation biases, asymmetries in prior experience and differences in recovery time are possible confounding factors in the analysis of Rowe *et al.* After controlling for these factors, we found no difference in blue and white wins. We further analysed contest outcomes of 71 other major judo tournaments and also found no winning bias. Our findings have implications for sports policy makers: they suggest that a white–blue outfit pairing ensures an equal level of play.

Keywords: sexual selection; aggression; status signalling; judo; competition outcome; human performance

1. INTRODUCTION

Certain colours, like red and orange, are sexually selected traits signalling male quality, aggression and dominance in a wide variety of organisms (e.g. Rowland 1989; Pryke *et al.* 2001; Maan *et al.* 2004; reviewed in Andersson 1994; Hill & McGraw 2006). In aggressive interactions, these colours may increase the likelihood of winning (Evan & Norris 1996; Baube 1997; Cuthill *et al.* 1997; Dijkstra *et al.* 2005; Pryke & Griffith 2006). This winning bias has traditionally been attributed to the inherently intimidating effect of red coloration on opponents. Interestingly, Hill & Barton (2005) reported a similar effect in human combat sports; they found that wearing of a red outfit was associated with a higher winning probability relative to wearing a blue outfit in the men's division of Greco-Roman wrestling, freestyle wrestling, boxing and tae kwon do. Recently, Rowe *et al.* (2005) proposed the idea that this effect is not unique for red coloration. They found in another human combat sport, judo, a significant winning bias for athletes wearing a blue outfit (*judogi*) compared with those wearing a white *judogi* during the 2004 men's Olympics. Here we argue that there exists no winning bias for blue and that their findings were confounded.

Two, not mutually exclusive, mechanisms have been proposed to underlie the winning bias for blue. First, Rowe *et al.* (2005) attribute the effect to blue and white colour having differential effects on opponent visibility. The white *judogi* may be more visible than the blue *judogi*, allowing the athlete in blue to better anticipate the movements of his (white) opponent. A second explanation was given by Barton & Hill (2005). They suggested that blue coloration is brighter than white, and may therefore have an intimidating effect on opponents, as was originally proposed for red coloration.

Both explanations are unlikely. Considering the first explanation, we believe that a differential perception effect is unlikely to occur in a situation where athletes fight at close quarters in brightly lit areas, as in judo (see Barton & Hill 2005).

Considering the second explanation, inherently intimidating effects of colour on opponents have been suggested for red coloration in a wide range of animal species (e.g. Dijkstra *et al.* 2005; Pryke & Griffith 2006) but never for blue coloration. For example, in a non-human primate, the intensity of red coloration on the nose correlated with dominance status (Setchell & Wickings 2005). In humans, anger may trigger increases in facial blood flow (Drummond 1999). In people with a fair skin, this facial reddening may alter the behaviour of others in social encounters (Drummond & Quah 2001). Therefore, the traditional intimidating nature of red coloration may influence dominance in humans (Hill & Barton 2005). Such an effect cannot be logically attributed to blue coloration.

We argue that athletes wearing a blue *judogi* are not more likely to win than those wearing a white *judogi*, and suggest that the results obtained by Rowe *et al.* (2005) were compromised by three confounding factors: (i) seeding system, (ii) inclusion of repechage rounds, and (iii) differences in recovery time.

First, wearing of *judogi* colour was not completely determined at random during the 2004 Olympics, even though athletes switch blue and white *judogi* depending on their position in the tournament bracket (electronic supplementary material). Top-ranked athletes were 'seeded' so as to avoid matching them against one another before the semi-finals; seeded athletes were given the blue

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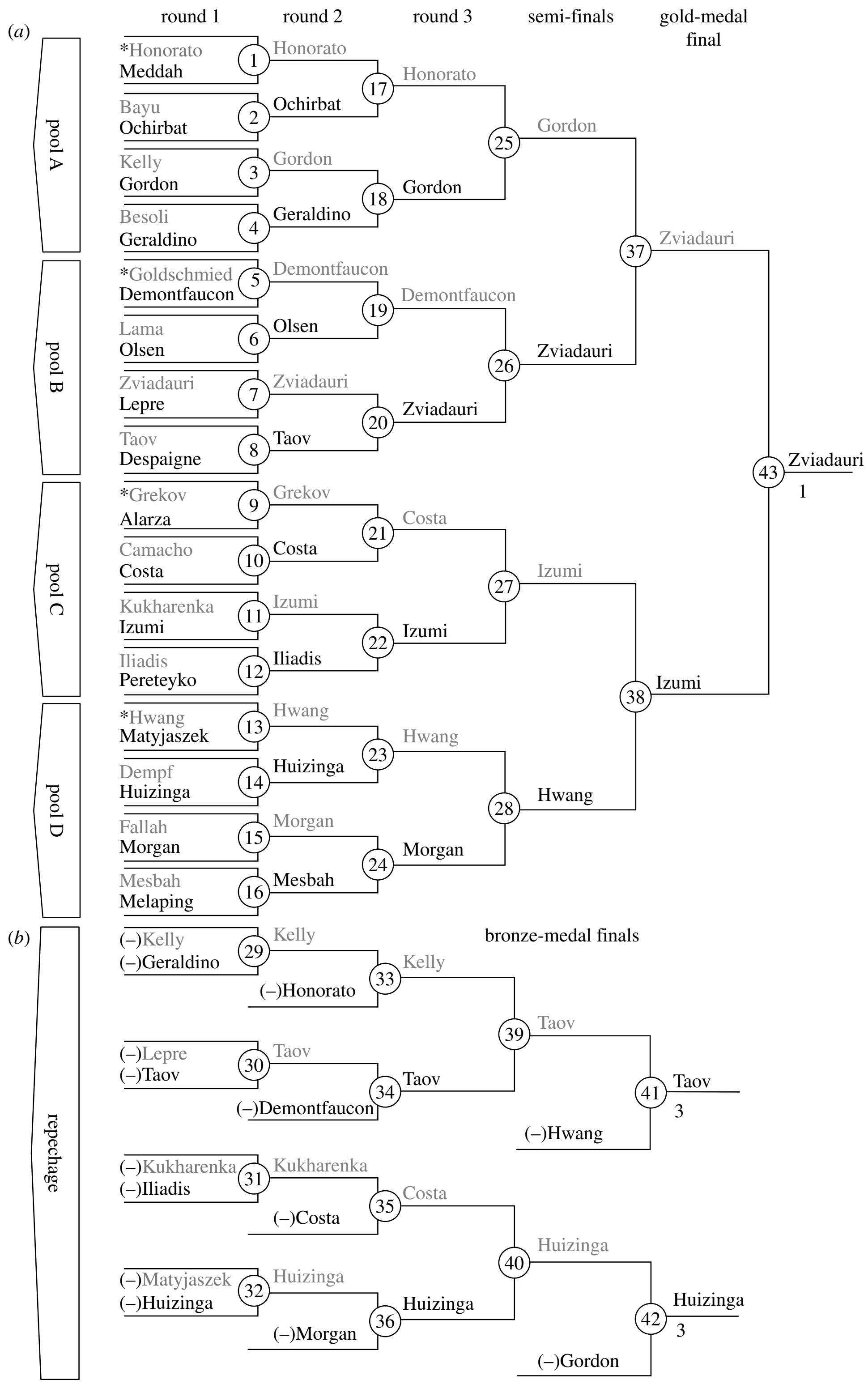

Figure 1. (*Caption opposite.*)

judogi by default in the first round, causing an athlete quality–colour association and a winning bias for blue. In their corrigendum (Rowe *et al.* 2006), this allocation bias was controlled for by excluding first-round matches. However, we show that this correction was insufficient, because seeded athletes have a higher chance to wear blue in the second and third rounds too, causing the athlete quality–colour association to persist (electronic supplementary material).

A second fundamental methodological problem concerns the fact that Rowe *et al.* (2005) included the loser's pool, or repechage in their analysis. In international tournaments, the modified double elimination system is used (www.ijf.org); athletes who win move to the subsequent round up to the gold-medal final. Under certain conditions, those who lose get another chance in the loser's pool where they can maximally win the bronze medal (figure 1). Many repechage matches contain systematic asymmetries in prior experience (win–lose and/or number of previous matches fought) and *judogi* colour. First, in approximately 50% of matches, an asymmetry in prior win–lose experience exists because the athletes in blue had won their previous match,

Figure 1. (*Opposite.*) Contest sheet for the men's 81–90 kg weight category of the 2004 Olympics. The four seed positions are indicated by an asterisk. Each match has a number. Athletes who lost their previous match are indicated by a (–); all other athletes won their previous match. Shown in the upper half is the winner's pool (leading to the gold-medal final) and in the lower half, the loser's pool or repechage (leading to two bronze-medal finals). This figure illustrates two confounding factors. (*a*) There is a difference in intercontest time interval between athletes in blue and those in white. Every pool is usually allocated to one mat. Matches take place sequentially from top to bottom per pool, with little time between subsequent matches (e.g. in pool A from matches 1 to 4; then 17, 18 and finally 25). Consequently, the intercontest time interval is on average longer for athletes in blue than for those in white, resulting in a longer average recovery time for those in blue. The difference in recovery time between blue and white is approximately the duration of one match. For example, in match 17, the winner of match 1 fights the winner of match 2. The athlete in blue of match 17 had thus the duration of one match longer to recover than the athlete in white. A judo match lasts on average 7.17 min (Sikorski *et al.* 1987), and this should be almost equivalent to the absolute difference in recovery time between blue and white athletes. The relative time difference was difficult to calculate, because we could not find published estimates of between-round time intervals. Recovery times are equal in the gold-medal final for athletes in white and blue, because the semi-finals are scheduled simultaneously. (*b*) The repechage contains asymmetries in prior experience and *judogi* colour. First, in approximately half of the matches, there is an asymmetry in prior win–lose experience and *judogi* colour; in these matches, the athlete who had lost his previous match starts in white against an opponent in blue who had won his. For example, in match 42, Huizinga, wearing blue, won his previous match while Gordon, wearing white, lost his. However, there are no matches with the opposite bias. Second, in the repechage, the athlete in blue is more likely to have experienced one match less than his opponent in white. For example, in match 29, Kelly, wearing blue experienced one match, whereas Geraldino, wearing white, experienced two matches. This asymmetry may occur in all repechage matches, depending on which colour progresses; it *can* occur with the opposite bias in the third round and bronze-medal final (overall, the chance that blue experienced one match less than white is 50.00%; the converse 11.11% and both equal number of matches 38.89%).

while the athletes in white had lost theirs. In the other 50% of the matches, this asymmetry in win–lose experience never occurs conversely with respect to *judogi* colour. Evidence indicates that prior defeat or victory can have a dramatic influence on the outcome of future aggressive encounters (Rutte *et al.* 2006). Second, an asymmetry can occur in the number of previous matches fought, with blue being more likely to have experienced one match less than his opponent in white (explained in figure 1). Possible asymmetries in prior experience associated with *judogi* colour require exclusion of the repechage matches.

Third, athletes wearing a blue *judogi* have on average in all international tournaments a slightly longer intercontest time interval than those who wear white, resulting in a longer recovery time for athletes in blue compared with those in white (N. van Dijk & K. Kienhuis 2007, personal communication). How this difference in intercontest interval comes about is explained in figure 1. In brief, each weight category is divided into four pools. Per pool matches take place sequentially from top to bottom, with little time in between matches, so that in the subsequent round the athlete in blue has had a longer recovery time than the one in white. Only in the gold-medal final are recovery times equal for the athletes in white and blue because the semi-finals are scheduled simultaneously.

In our study, we test whether there is a winning bias for blue in judo in two ways. First, we re-analysed the data of the 2004 Olympics of Rowe *et al.* (2005). If there is no effect of colour on winning, the winning bias for blue as reported by Rowe *et al.* should disappear when controlling for the confounding factors. In addition, if there is no effect of colour, we predict that the winning bias for blue declines over the tournament rounds when we include seeded athletes. This is because only the strongest competitors are expected to progress in the tournament, thereby reducing differences in athlete ability.

Second, we analysed in addition to the 2004 Olympics a total of 71 other international judo tournaments, thereby avoiding possible effects specific to a single tournament. We compared the number of blue and white winners in 501 gold-medal finals to avoid a biased sample due to the seeding system, asymmetries in prior experience and recovery time. We predict no colour-associated winning bias in the gold-medal finals.

2. MATERIAL AND METHODS

(a) *Tournaments analysed*

For our re-analyses of Rowe *et al.* (2005)'s data, we will (obviously) use the results of the 2004 Olympics.

For the tournaments in our second additional analyses, we obtained as many contest outcomes as possible of major international tournaments held between 1996 and 2005. (The blue–white *judogi* pairings have been used in international competition since 1996 instead of white–white pairings to improve differentiating the two contestants.) Our dataset included 72 international tournaments (Olympic Championships, $n=2$; World Championships, $n=7$ (including three Junior World Championships, less than 20 years); European Championships, $n=9$; Super A Tournaments, $n=15$ and A Tournaments, $n=39$).

The results are from the International Judo Federation and the European Judo Federation. In all analyses, we focus on the men's division, following Hill & Barton (2005) and Rowe *et al.* (2005), and on the winner's pool (thus excluding repechage matches). In some tournaments, there is an open weight category; in this non-Olympic category, athletes from all weight categories can compete. We excluded this category in our analysis, because we expect substantial ability asymmetries between athletes due to large weight differences.

(b) *Procedure*

(i) *Analysis 1: re-analysis of the 2004 Olympics*

We compared the number of blue and white winners after excluding matches involving a seeded athlete. We excluded contests involving a seeded athlete, because seeded athletes had a bigger chance of wearing blue in the first three tournament rounds. We found that 11% of contestants were seeded. They started in a blue *judogi* in their first match with a winning chance of 84%. In Rowe *et al.* (2006)'s corrigendum, this association between the blue *judogi* and winning was removed by excluding first-round matches. However, this is insufficient, because the association also affected other rounds; seeded athletes had a 66.7% chance of wearing blue in the second and third rounds, with winning probabilities of 85.7 and 55.6%, respectively (see electronic supplementary material for an example of a tournament programme and explanation of how the seeding system can affect the probability of wearing blue).

In our analysis, we did not control for differences in recovery time. In the gold-medal finals, recovery times between athletes are equal (see below). However, the sample of the gold-medal finals is too small ($n=7$) to make valuable comparisons. We also tested whether the difference in athlete quality as well as the association between winning probability and *judogi* colour declined over the tournament rounds when seeded athletes are included in the analysis.

(ii) *Analysis 2: comparing the number of white and blue winners in 72 tournaments*

We compared blue and white winners in 501 gold-medal finals of 72 tournaments.

We only focus on the finals because (as explained in §1) (i) the seeding system can cause non-random allocation of *judogi* colour as in the 2004 Olympics and (ii) intercontest intervals (and thus recovery times) are not the same for athletes in blue and white. To check whether the seeding system indeed can cause the non-random allocation, we performed an analysis on the eight most important tournaments held between 2003 and 2005 (2003 and 2005 World Championships; 2004 Olympic Championships; 2003, 2004 and 2005 European Championships; 2005 Hamburg Super A Tournament and 2005 Paris Super A Tournament). Regulations concerning the seeding system were obtained from the International Judo Federation, the European Judo Union, the Dutch Judo Federation and the Swiss Judo and Jiu-Jitsu Federation. We then verified regulations governing the allocation of seedings by examining the contest sheets of the tournaments (downloaded from www.ippon.org). To this end, we checked whether athletes ranking numbers 1–7 in the most recent World and Olympic or European Championships, were consistently separated over the pools; we then checked whether they started in the blue *judogi* by default. We found that in all tournaments except in the 2004 European Championships such 'high-quality' athletes were seeded. The seeded athletes were given the blue *judogi* by default in their first match of all tournaments except in the 2003 European Championships (table 1). The starting position on the contest scheme determines the chance to wear blue when an athlete progresses through the tournament. We found that the starting position of seeded athletes is such that the association between winning and blue *judogi* may affect all rounds up to the pool finals. This is fully explained in the electronic supplementary material. Therefore, correcting for seeds should be done by excluding those affected matches.

(c) ***Statistical analysis***

We used χ^2-tests to compare the number of blue and white winners. Logistic regression was used to test whether the proportion of blue winners declined over the tournament rounds in the 2004 Olympics. Tests of significance were two-tailed, unless we have a one-directional alternative hypothesis. Analyses were done using SPSS v. 12.0.1.

Table 1. The seeding system for eight international judo tournaments. (Shown are the percentages of seeds starting in blue in the first round. Note that there were no seeds during the 2004 European Championships.)

tournament	percentage of seeds starting in blue
Olympics 2004	100
World Championships 2003	100
World Championships 2005	100
European Championships 2003	74
European Championships 2004	no seeds
European Championships 2005	100
Super World Cup Paris 2005	100
Super World Cup Hamburg 2005	100

3. RESULTS

(a) ***Analysis 1: re-analysis of the 2004 Olympics***

When excluding the matches involving a seeded athlete, the winning bias for blue disappeared as expected (proportion of blue wins$=0.539$, χ^2-test: $\chi_1^2=0.858$, $p=0.4$, $n=141$ contests).

If matches with a seeded athlete are included, we expected under the null hypothesis of no effect of colour that the difference in athlete ability as well as the association between winning probability and *judogi* colour would decline over the tournament rounds. This was indeed the case (logistic regression with covariate 'round' Wald$=3.293$, d.f.$=1$, $p=0.0348$, one-tailed).

(b) ***Analysis 2: comparing the number of white and blue winners in 72 tournaments***

In the gold-medal finals, there was no winning bias for either colour, as expected (figure 2; proportion of blue wins$=0.507$, χ^2-test: $\chi_1^2=0.098$, $p=0.8$, $n=501$ finals).

(c) ***Effect of seeding system***

The 72 tournaments allow us to further analyse the effect of seedings and colour on winning. In 2004, the European Judo Federation doubled the number of seedings, each starting in blue by default (R. Abächerli & N. van Dijk 2007, personal communication). More colour–quality associations predict a stronger winning bias for blue. Consistently, the proportion of tournaments with a significant winning bias for blue was much higher after 2003 (1996–2003: 4 out of 52 tournaments, 2004–2005: 10 out of 20 tournaments, χ^2-test: $\chi^2=9.83$, $p=0.0009$, one-tailed).

4. DISCUSSION

Our results show that in judo blue–white outfit pairings do not affect contest outcomes. This is consistent with our expectation and contrasts the findings of Rowe *et al.* (2005). They corroborate the suggestion that a differential perception effect due to colour differences is unlikely in close combat sports, such as judo (Barton & Hill 2005). The findings also contrast the suggestion of Barton & Hill (2005) that the brightness of blue intimidates the opponent.

Rowe *et al.* (2005) attributed their findings in judo to the higher visibility of the white opponents, conferring an advantage to blue contestants in being better able to perceive and anticipate their white opponent's moves.

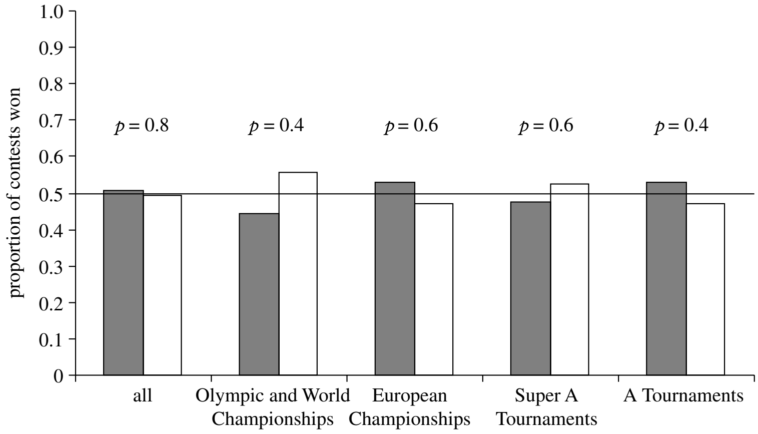

Figure 2. Lack of an effect of *judogi* colour on the outcome of men's gold-medal final judo matches (1996–2005, $n=501$). There was also no effect when the gold-medal finals were analysed separately for the Olympic and World Championships ($n=63$), European Championships ($n=64$), Super A Tournaments ($n=105$) and A Tournaments ($n=269$). Data are from a total of 72 international judo tournaments (for details, see §2). The black line at 0.5 indicates the expected proportion of wins by blue or white under the null hypothesis that colour has no effect on contest outcome. Black bars, proportion won by athletes in blue; white bars, proportion won by athletes in white. No significant differences exist between the number of blue and white wins (p values are indicated at the top).

This hypothesis is not convincing for judo, because, if anything, the light grey or yellow background of the judo floor would make white *judogis* less visible than blue *judogis* (see www.judophotos.com).

We argue that in international judo tournaments four factors can confound a comparison between blue and white winners. First, many matches in the repechage are asymmetric with respect to prior win–lose experience and *judogi* colour. Second, in the repechage, athletes in blue are more likely to have experienced one match less than the athlete in white. Third, in many tournaments the seeding system results in the allocation of blue *judogis* to top-ranked athletes, creating an athlete quality–colour association even beyond the first round. Regulations on the draw and seeding system are subject to change and may vary by tournament. In the same tournament, they may even differ between the men's and women's divisions. For example, during the 2004 Olympics, all seeded athletes in the men's division started in blue, while in the women's division 19 out of 25 athletes started in blue, but we found no official document describing this. It is therefore critical for investigators to carefully examine the seeding system of a particular tournament before testing a hypothesis. Finally, athletes in blue have on average a longer recovery time than those in white. Although the difference in recovery time is small (7.17 min; Sikorski *et al.* 1987), it can nevertheless (slightly) increase the likelihood of winning for athletes wearing a blue *judogi*, because judo is a physiologically very demanding sport that often leaves athletes exhausted after a match (Degoutte *et al.* 2003).

We suspect that the factors described in the previous paragraph may also compromise analyses on colour-associated winning biases in other sports. One could therefore also ask for a more specified analysis of the findings of Hill & Barton (2005) in which they describe a winning bias for red in four Olympic combat sports. A critical re-evaluation is also necessary for other recent analyses of colour-associated winning biases in sports (tae kwon do: Ioan *et al.* 2007; judo: Matsumoto *et al.* in press). Matsumoto *et al.* (in press) reported a highly significant winning bias for blue in the men's division of four major international judo tournaments (2001, 2003, 2005 World Championships; 2004 Olympics), but overlooked the same factors as Rowe *et al.* (2005). We re-analysed the same data and excluded the repechage and matches with seeds. Despite the fact that the asymmetry in recovery time was not controlled for, the winning bias for blue disappeared (proportion of blue wins $=0.525$, χ^2-test: $\chi^2_1=2.698$, $p=0.1$, $n=1041$ contests). In general, we call for more careful analyses to determine whether colour-associated winning biases exist in human combat sport in the first place.

Despite our efforts to control for possible confounding factors, we believe that our analysis is still somewhat limited, in that it had no experimental approach. For example, athletes in blue and white always have fixed left and right positions relative to the scoring board. Experimental work is needed to rule out any possible confounding variable.

The general intimidating nature of red may explain the red-associated winning bias in human combat sport (Hill & Barton 2005). Given this explanation, critical investigations on how colour can impact on psychological functioning and performance in combat sports are necessary. Viewing colour can impact on mood, behaviour, cognition tasks and brain activity (Kwallek *et al.* 1997; Vrij 1997; Elliot & Maier 2007; Ioan *et al.* 2007). For example, Elliot & Maier (2007) described a series of intriguing experiments showing that red evokes avoidance motivation, thereby undermining intellectual performance. Such effects of colour may arise from cultural associations, which themselves may have an evolutionary basis (Elliot & Maier 2007). Black is associated with evil and death in virtually all cultures (Adams & Osgood 1973). Frank & Gilovich (1988) found that teams of the National Football League and the National Hockey League with black uniforms were penalized more often (but see Mills & French 1996; Tiryaki 2005). Additional experiments revealed that this might be due to referees being more prone to penalize athletes wearing black and an increased aggressiveness in players wearing black (Frank & Gilovich 1988). Although more empirical investigations are needed, the existing research supports psychological effects of red and black, but not of blue, on performance in sports.

In summary, we found no effects of winning in athletes wearing blue outfits versus white outfits. These results may have important implications for sports policy makers in judo, the most widely practised competitive martial art; we show evidence that the blue–white judo outfit does ensure an equal level of play. If the findings of Hill & Barton (2005) are reliable, it may also affect the four Olympic combat sports for which they showed a winning bias for athletes wearing red outfits; our results suggest that a blue–white pairing may be a suitable and fair alternative.

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