Handedness is the most obvious expression of lateralization of behaviour in humans. Although lateralization is now recognized as a fundamental principle in the organization of brain and behaviour throughout the animal kingdom, very few species show such a strong bias in limb preference as humans (Groothuis et al. 2013). Human left-handedness has always occurred at a clear minority throughout human history and across cultures (Steele & Uomini 2005), and large populations seldom exceed proportions of 10% left-handers. This is in contrast with data from other primates, including great apes, where the population bias for hand preference is much less strong and appears more variable (Hopkins et al. 2011; see Cashmore et al. 2008 for a review). The low relative frequency of human left-handedness has been explained by its association with traits that lower Darwinian fitness such as low birth weight, higher prevalence of some diseases and delayed maturability (for a review see Llaurens et al. 2009). Human handedness has furthermore been shown to be heritable, with a (broad) heritability estimate of 25.9% (Medland et al. 2006; also see Sicotte et al. 1999; Francs et al. 2002), giving rise to the question of why left-handedness did not disappear from human populations by natural selection.

One evolutionary hypothesis for the persistence of the minority in human left-handedness is ‘the fighting hypothesis’ (Raymond et al. 1996; Faurie & Raymond 2013; see Groothuis et al. 2013 for a review). This hypothesis suggests that the fitness-adverse effects of left-handedness are balanced by its advantage in (male–male) physical aggression. This advantage arises because most males in the population are right-handed, and therefore trained in combat against right-handed fighters, providing left-handers a competitive advantage partially because of a surprise effect when fighting. Because the advantage of left-handedness is due to its low frequency, the advantage is upheld only when the number of left-handers in the population remains a minority: a case of negative frequency-dependent selection (Raymond et al. 1996; Faurie & Raymond 2005). An alternative mechanism to a surprise effect as a mechanism for a frequency-dependent advantage could be that right-handers have an impaired domain-specific perceptual-cognitive performance such as a reduced ability to predict a left-handers’ action outcome (e.g. McMorris & Colenso 1996; Hagemann 2009; Loffing et al. 2012a) or maladaptations in game play behaviour (Loffing et al. 2010).

Some preliminary evidence for the fighting hypothesis does exist, as left-handers are often overrepresented in combat sports, such as boxing, karate and judo, compared to the general population (Raymond et al. 1996; Grouios et al. 2000). This over-representation of left-handers does not seem to be restricted to combat sports, but extends to noncombat sports such as badminton.
(Raymond et al. 1996), tennis (Grouios et al. 2000; Holzten 2000) and cricket (Wood & Aggleton 1989), to name a few (see Grouios et al. 2000 for a review). Few studies, however, address the question whether left-handers have a higher likelihood of winning, as would be expected on the basis of the ‘fighting hypothesis’. One study examining handedness in tennis did find evidence for a left-handed advantage, and also found, in accord with the hypothesis, that the advantage attenuated with more experience of the players (Loffing et al. 2012b). Two studies investigated other noncombat sports, cricket (Brooks et al. 2004) and baseball (Goldstein & Young 1996), and only in cricket was there some evidence for a frequency-dependent advantage of left-handers, with left-handed batsmen having more success than right-handed batsmen, especially when playing against low-ranking teams that might have less experience with left-handers. These three sports are clearly not dyadic physical combat sports, but a similar left-handed advantage has been documented in a true combat sport, boxing (Gussoy 2009), although this study had a very small sample size. Based on a much larger sample size Ziyagil et al. (2010) reported that in wrestling (Brazilian) jiu-jitsu, karate, muaythai, and even street fighting hypothesis owing to an extensive set of rules and to that both costs and benefits are substantial, as it would be in fighting over important resources in our evolutionary history. Ultimate fighters regularly suffer grave injuries in their career, whereas the gains are also very substantial; many of the UFC fighters are professionals who can earn large sums of money (Folx 2012). For example, one fighter is reported to make $400 000 for a single fight (MMAJunkie 2011). Moreover, using data from real combat competitions might counter some of the limitations of self-reporting of fighting experience by students (Faurie et al. 2011). With respect to the fighting hypothesis, our aims were twofold: we tested first whether there is an overrepresentation of left-handers in ultimate fighting and second whether or not left-handers have an advantage when facing a right-hander.

**METHODS**

Videos of 210 UFC fights (UFC broadcasts 118–148; August 2010–July 2012) were coded by the first author for handedness with handedness classification (right or left) based on predominant fighting stance during the fight: ‘orthodox’ versus ‘southpaw’, in a similar way as is done for boxing. Fighting stance is a good proxy for handedness as in boxing as well as other martial arts, it is recommended that the ‘power hand’, indicating hand preference, corresponds to the back leg, rather than the lead leg. From observing over 40 h of these fights, we found that this pattern is also clearly present in the UFC (and is frequently commented upon by the UFC’s commentators). Fighters use the hand in front to jab and/or measure the distance to their opponent, while using the hand corresponding to the back leg for more heavy punches. UFC Fighters only rarely switch between stances within or between fights unless their lead leg is so severely injured that they have to switch.

Fighters participate in multiple fights, so we had 246 fighters rather than 420 fighters (137 fighters fought one fight, 62 fought two fights, 31 fought three fights, 14 fought four fights and two fought five fights). One fighter (Jon Jones) switched stances often during his fights, although he predominantly used a southpaw stance; he was therefore coded as southpaw, but could be coded as ambidexter. Excluding this fighter does not alter the results reported below qualitatively. There was only one fighter (Claude Patrick) who switched handedness between fights: we excluded the two fights in which he fought.

The proportion of left-handers in males was tested against the expected frequency of 12.6% of left-handed males, based on a large population sample (>1000 000 males; Gilbert & Wysocki 1992) using a binomial test. This baseline sample was recruited via National Geographic magazine and the estimate of 12.6% is based on self-reported writing and throwing (Gilbert & Wysocki 1992). This value is likely to be an overestimate of the actual percentage of left-handers in the general population, as using a left hand for either writing or throwing would be coded as left-handed. The estimate of 12.6% is thus conservative with respect to the fighting hypothesis. Another large internet study covering over 250 000 individuals found, based on just writing hand preference, estimates for exclusive left-handedness in males ranging from 7% to 11.8% across various ethnic groups (Peters et al. 2006). For our purpose we used the most conservative estimate: the 12.6% from Gilbert & Wysocki (1992). This study not only used a much larger data set, but also included throwing, more relevant for estimating handedness in a fighting context than writing.

Three fights ended in a draw, which we excluded from the analyses on success, leaving 205 fights available (also excluding the two fights by Claude Patrick): 11 left–left fights, 68 left–right fights, and 126 right–right fights. We used two different types of
analyses to examine a possible left-handed advantage. First, using a
binomial test we examined whether left-handers were more likely
to win a fight against a right-hander. More specifically, we inves-
tigated how many fights between a left-handed fighter and right-
handed fighter \(N=68\) were won by the left-hander. This anal-
ysis, however, does not account for the fact that fighters engage in
multiple fights. To account for this nonindependence, we took a
randomization approach. First, we determined how many of the
205 fights were won by a left-hander \(N=45\). Then, we random-
ized the handedness of all fighters, while retaining similar values of
both the number of fights and the number of victories for each
fighter. In this way, the likelihood of winning with respect to
handedness was purely based on chance. We kept the number of
left-handers and right-handers in every randomization similar to
that in the actual fights \(50\) left-handers and \(194\) right-handers). We
performed 1000 randomizations and, from these, calculated
the median value and 95% range of left-handed wins. If the \(45\) times
that a left-hander won in the \(205\) fights falls outside \(95\%\) range of the simulations, we can conclude that left-handers
are significantly more likely to win a fight against a right-hander.

**RESULTS**

Among UFC fighters, \(20.4\%\) were left-handed \(\left(50 \right)\) of \(245\)
fighters), which is a significantly higher percentage compared to
that of the general male population \(0.204\) versus \(0.126\), respectively; binomial test: \(P < 0.001\); Fig. 1a).

When examining the proportion of fights won by left-handers
(thereby ignoring the nonindependence in the data introduced by
fighters participating in more than one fight), we gain an easy to
interpret effect size for the left-hander advantage. Limiting the
sample to only those fights in which a left-hander faced a right-
hander, we found that left-handers won exactly half \(34\) of \(68\)
fights; one-tailed binomial test: \(P = 0.5\); Fig. 1b). Sensitivity power
analysis indicates that we should be able to detect a relatively weak
effect at a power of \(0.8\) \(\left(\text{odds ratio: 1.94 (proportion of 0.66 versus 0.5)}\right)\); one-tailed; \text{Faul et al. 2007}.

Via our randomization approach, we found that left-handed
fighters were predicted to win \(42\) fights \(\left(\text{median of 1000 ran-
domizations), with a 95% range between 31 and 53}.\right)\). The observed
value of \(45\) left-handed victories is both very close to this median
value and falls well within the \(95\%\) range, and is therefore not
different from chance \(\left(\text{one-tailed } P(x \geq 45) = 0.303; \text{Fig. 2}\right)\).

**DISCUSSION**

We found that left-handers are substantially overrepresented
among the mixed martial art fighters from the UFC, as in other
combat sports (e.g. \text{Raymond et al. 1996; Gursoy 2009}). However,
unlike a previous finding from boxing (\text{Gursoy 2009}), evidence for
significant elevated winning chances for left-handers, as predicted
by the fighting hypothesis, were not found. In contrast to other
popular combat sports, which are more restricted by rules, we
believe that fights within UFC more closely emulate fights as they
would have occurred in natural settings throughout human
history. Moreover, the UFC incorporates and combines a wide range
of fighting styles such as wrestling, boxing, muaythai, Brazilian jiu-
jitsu, judo and many more, which have been practised in many
different cultures and are ‘proven’ combat styles over time.

The overrepresentation of left-handers among the UFC fighters
could potentially be explained by the left-handers having a
competitive advantage relative to right-handed fighters. However,
this was not the case in our sample, as left-handers did not have a
higher likelihood of winning a fight against a right-hander,

---

**Figure 1.** (a) Percentage of left-handed UFC Fighters and (b) percentage of fights won by a left-hander when facing a right-hander; 12.6% is based on a population estimate by \text{Gilbert & Wysocki (1992)}. Error bars represent 95% confidence intervals based on the Agresti–Coull method.
suggesting that there is little evidence for a competitive advantage for left-handers in UFC professionals. Our results are based on both a simple binomial test and a simulation approach, which both show no evidence for a left-handed advantage.

Our tests do not necessarily indicate that left-handedness provides no competitive advantage at all in physical combat; it is possible that left-handers at nonprofessional levels enjoy a competitive benefit, leading to selection into professional UFC by increased chances of winning (which would lead to the overrepresentation of left-handers in our sample), whereas the benefits of left-handedness cease to exist when competing at the highest level. There are two nonmutually exclusive explanations for this possibility. First, left-handers may be prevalent to such a high degree within the UFC, that the advantage of left-handedness is diminished because right-handed fighters regularly have to deal with left-handed fighters. Second, professional right-handed fighters may themselves realize the left-hand advantage, and will regularly train against ‘southpaws’. Amateurs, in contrast, may not have the time, resources or dedication to train similarly against left-handers, which would lead to a competitive advantage of left-handedness in the amateur setting. This advantage, in turn, could potentially make them more likely to be selected into the UFC. This possibility is in line with a recent study on handedness in tennis (Loffing et al. 2012b). This study showed that the beneficial effect of left-handedness in male professional tennis has decreased over the past 40 years and the authors suggest that this is because, as training regimes continue to improve, any benefits that left-handers might have become attenuated. Moreover, cross-sectional data from this study suggest that, in contrast to professional tennis, in nonprofessional tennis left-handers perform better.

While the current study is partially in line with the fighting hypothesis, alternative explanations for the overrepresentation of left-handers in combat sports can also account for our results. Rather than the frequency-dependent advantage left-handed fighters have when fighting right-handers, selection of left-handers into ultimate fighting could also be the result of their potential innate superiority (Grouios et al. 2000), more specifically caused by their potentially superior motor skills (e.g. Judge & Stirling 2003). For example, data from fencing suggest that left-handers have improved hand–eye coordination over right-handers (Taddei et al. 1991). There is also some evidence pointing to an advantage for left-handers in motor performance in the nondominant hand (Judge & Stirling 2003), as well as advantages in visual ability for left-handers when focusing on points (Dane & Gümüstekin 2002). More data on neuropsychological performance on left-handers versus right-handers in acts relevant for fighting would be necessary to test this alternative explanation further. However, one could argue that an ‘innate superiority’ explanation would suggest an overrepresentation of left-handers not only in combat sports but also in noninteractive sports involving fine motor skills but this is not the case (Grouios et al. 2000; see Loffing et al. 2012a). Yet, many noninteractive sports tend to require much slower motoric adjustments than interactive sports so that right-handers have to keep compensating for poor motor skills by taking more time (e.g. in darts, golf). Since left-handers did not have an advantage in fights in our data set, we did not find direct evidence for the innate superiority hypothesis either, as left-handers were not more likely to win fights than right-handers. The finding that left-handers are overrepresented, but do not win more fights in our sample could thus be explained by both innate superiority and the existence of a frequency-dependent advantage. We believe the latter explanation to be more likely, based on the above-mentioned literature that suggests that the advantage of left-handedness is apparent in amateurs but not in highly trained professionals that will have extensive experience with left-handed players. This is consistent with the lack of winning advantage we found here in the UFC.

Another explanation for the overrepresentation of left-handers in UFC is that left-handers may simply have more affinity with fighting sports or are more aggressive than right-handers. In this case the overrepresentation of left-handers is due to their motivation, rather than their handedness per se, which may not lead to higher winning chances and therefore fit our data best. In line with this, Dane & Şekertekin (2005) showed that left-handed football players were more aggressive and less tolerant than right-handers.

Both the ‘innate superiority explanation’ and the ‘increased aggression’ explanation are different from the fighting hypothesis in that only the latter assumes negative frequency-dependent selection: the success of left-handers is dependent on the proportion of left-handers in the population. To distinguish between these alternative explanations one could, for instance, analyse the effect of training and experience: if left-handers are simply superior or more aggressive than right-handers, then no amount of training against left-handers by right-handers will change the likelihood of winning against left-handers. More longitudinal data on the effect of fighting experience with left-handers is necessary to distinguish between these alternative explanations. In addition, experiments manipulating such experience with animal species other than humans may be helpful (Groothuis et al. 2013). For now we have shown that while there is substantial overrepresentation of left-handers in UFC fighters, left-handers have no advantage in fights that may closely resemble the way of fighting in human history.

Acknowledgments

We thank two anonymous referees and the editor for helpful comments, which substantially improved the manuscript. We thank Tim Fawcett for advice on the simulation model. T.P. is supported by The Netherlands Organisation for Scientific Research (452-10-012), granted to M. Mills.
References


