The relationship between number of potential mates and mating skew in humans

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ARTICLE INFO

In nonhuman animal mate choice, a small number of (usually male) options typically leads to an unequal distribution of selections (usually by females) across the options, indicating adaptive choice; conversely, an increasing number of mate options typically yields less inequality of choices across the options. We examined mating skew, a measure of this inequality in mating choices, among humans by considering the offers made by participants in 118 speed-dating sessions of various sizes. Overall, the relationship between a number of indices of mating skew and option set size (the number of opposite-sex participants in the speed-dating session) was positive, with larger sessions producing more mate choice inequality. This result contrasts with the negative relationship between skew and option set size found in nonhuman animals. We interpret these results as the outcome of similar choice mechanisms but different cues used by humans versus other species when making a choice from an abundance of mates.
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Female mate choice in leks and other mating systems with relatively simultaneous presentation of suitors (e.g. polygamous groups) typically results in nonrandom variation in the reproductive success of the males (Höglund & Alatalo 1995). A few males meet with a great deal of success, whereas others have little or even no success. Inequality in mating success, a necessary underpinning of the theory of sexual selection (Darwin 1874; Kokko et al. 1999), can be quantified via measures of mating (or reproductive) skew. Studies of mating skew demonstrate that dominant males in a variety of species, including nonhuman primates, obtain more matings than would be expected by chance (Höglund & Alatalo 1995; Constable et al. 2001; Alberts et al. 2003). While random (as opposed to evenly distributed) choices can generate some skew (Kokko et al. 1999), mating skew will be even stronger when choice criteria are relatively stable within and consensual across individuals (Isvaran 2005).

Humans possess stable and somewhat universal preferences regarding the characteristics that their ideal mate should possess (Buss & Barnes 1986; Li et al. 2002; Buston & Emlen 2003). Furthermore, much of human mate choice could be argued to occur in an environment similar to that facing nonhuman animals that mate in aggregations. Humans often choose mates in contexts that require the rapid assessment of a multitude of options in close spatial, or psychological, proximity. For example, parties and other social gatherings (and tribal gatherings in our ancestral past) permit many people to meet at once, and this format has been institutionalized in speed-dating events that allow several men and women to meet face-to-face in a couple of hours (Kurzban & Weeden 2005; Finkel et al. 2007; Todd et al. 2007). Even greater choice is available in online dating services such as match.com and eharmony.com, which enable single people to assess tens of thousands of potential mates (Lenton et al. 2008). Of course, purposefully evaluating so many potential mates in such a short time is a rather new method of encountering mates for humans. The question we sought to answer in the present study is whether people choosing from a collection of potential mates behave as other species do in a similar choice context. To this end, we obtained data from over 100 speed-dating sessions to examine mating skew in humans. For the uninitiated, speed dating is a sped-up form of sequential mate choice (Penke et al. 2007; see also see

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Finkel et al. 2007). A typical speed-dating event involves several women meeting several men in a sequence of one-on-one 'minidates', with each such encounter lasting around 5 min. At a minidate's end, participants record whether they are interested in seeing this other person again. Expressions of interest or 'offers' are the behaviour that we analysed throughout this paper: offers, like visits on a lek, are indications of initial preference, and thus they are precursors of future 'mating success' in this domain (e.g. Andersson 1989; Robson et al. 2005; cf. Höglund & Alatalo 1995). After a speed-dating session, couples who expressed mutual interest in each other are given each other's contact information so that they can arrange to meet again.

Importantly for the present research, evidence from studies investigating mating skew in nonhuman animals suggests that skew diminishes when the number of options from which to choose is larger (Cowlishaw & Dunbar 1991; Widemo & Owens 1995; Kokko et al. 1999; but see also Charpentier et al. 2005). In other words, as the option set size increases, males of high rank will achieve relatively fewer matings and low-ranking males will achieve relatively more matings, thus flattening the distribution of mating success across the competing males. If humans behave similarly when faced with an extensive set of options, we should find that mating skew decreases as the number of opposite-sex speed-daters increases. And given that women are the 'choosier' sex (Trivers 1972), we should also observe greater mating skew among men being chosen.

Several hypotheses have been put forward to account for the negative correlation between option set size and mating skew among nonhuman animals. One hypothesis is that larger aggregations are more likely to contain coalitions of lower-ranking males who work together to displace the dominant male, reducing his mating success advantage relative to theirs (Alberts et al. 2003). Another explanation is that dominant males in larger aggregations may suffer from exhaustion (e.g. physical, running out of sperm, etc.) if they attempt to monopolize all attending females and prevent lower-ranking males from interfering (Rosenqvist 1990). Perhaps more relevant to the human context, some researchers have suggested that the quality of choice diminishes when females are faced with a large number of potential mates because their assessment process is 'imperfect', that is, females cannot identify the 'best' male(s) with perfect accuracy (Johnstone & Earn 1999; Luttbeg 2004). Thus, they may not always be able to distinguish the best from similar second-bests, and from a statistical point of view, similar options are likely to be even more similar to one another in larger aggregations (Johnstone & Earn 1999). This fact, alongside the increased search costs and time pressure that coincide with having more options (assuming the chooser adopts the same, extensive search strategy regardless of the size of the option set), suggests that assessment accuracy will be reduced when one has more potential mates to select from. In short, when presented with many (versus few) options, females may be more likely to confuse a lower-quality male for a higher-quality male, leading to reduced mating skew. If human mate choice in speed-dating events operates according to these same principles, then we should observe this same negative relationship between option set size and mating skew.

On the other hand, human mate choice in speed dating is also distinct in important ways from the mate choice of animals selecting from aggregations. In particular, speed dating allows participants to make and receive multiple, concealed offers, separated from the influence of other individuals. Consequently, lower-ranking speed-dating participants cannot band together to overthrow their higher-ranking competitors. And we found that the probability of making an offer is constant across all dates in a session, regardless of the session size, thus demonstrating that exhaustion is not an important factor for human speed-daters.

Thus, some of the primary explanations for the negative relationship between mating skew and the number of mate options seem largely irrelevant for speed-daters. As a consequence, there is reason to suspect that the relationship between human option set size and mating skew in speed-dating sessions could differ from that found among nonhuman animals. To summarize, in the present study we investigated the extent of mating inequality among human speed-daters, focusing in particular on how mating inequality is impacted by the number of potential mates available to the chooser, thereby allowing us to make comparisons with the mate choice processes of other animals.

METHODS

We obtained the data of 118 speed-dating sessions run between 2003 and 2004 in seven German cities by FastDating, a Munich-based company. Across these sessions, the number of male participants ranged from 8 to 34 ($\bar{X} \pm SD = 17.60 \pm 5.22$) and the number of female participants ranged from 7 to 36 (17.26 ± 5.42). Thus, there was substantial variation in the number of options from which the participants in different sessions could choose. The number of both sexes participating in a session was highly correlated across sessions as expected from the design of speed dating (Pearson correlation: $r_{116} = 0.85$, $P = 0.001$; and we note that a positive correlation between the number of males and number of females is also true of primate groups more generally, see Kutsukake & Nunn 2006). Importantly for our examination of potential sex differences, Levene's test indicated that variance in the number of available options was equal for men and women ($t_{232} = 0.24$, $P = 0.81$).

In the FastDating sessions, every member of each sex met with every member of the other sex, with each minidate lasting approximately 5 min. From the scorecards that participants carried throughout each session, we obtained the number of offers (expressions of interest) each participant made (and to whom), as well as the number of offers each received (and by whom).

Operationalization of Mating Skew

Per Kokko et al.'s (1999) recommendation regarding testing for mating inequality, we analysed our data using several skew measures. Although all mating skew measures purport to provide an indication of the degree to which mating success varies across individuals, they do so based on distinct theoretical and statistical frameworks, each having their own advantages and disadvantages, and, thus, they do not always produce identical results (Kokko et al. 1999; Nonacs 2000, 2003a). We used Nonacs's (2003b) Skew Calculator program to compute eight indices of mating skew for each FastDating session. All of these measures aim to quantify the distributional dispersion, or variance, in mating success across the competitors, with some also trying to control simultaneously for random factors or compare the result to the maximum possible value of skew, or even take into account the amount of time each competitor spent in the group (see Kokko et al. 1999 and Nonacs 2000 for a detailed explanation of each measure). Because three of the indices were effectively redundant with at least one of the other five (simple $r > 0.85$), we only discuss those five measures: Keller's corrected skew, or S_c (Keller & Krieger 1996); Pamilo's linear skew, or S_3 (Pamilo & Crozier 1996); the standardized Morisita coefficient, or I_p (Tsuji & Tsuji 1998); the binomial skew index, or B (Nonacs 2000); and the iterative skew index, or λ (Kokko & Lindström 1997). To the extent that these measures produce the same relationship between number of options and mating skew, we can be confident in our interpretation of that relationship (Kokko et al. 1999).

For all these skew measures a value of 0 indicates that mating is random (or is evenly distributed, in the case of S_3), while a value

greater than 0 indicates that mating is to some extent monopolized (complete monopolization yields a value of 1 for all measures but B). Thus, if the relationship between number of options and mating skew in speed-dating humans is similar to that typically observed among nonhuman animals, we should find a negative relationship between number of options and these measures of mating skew (i.e. as the number of options increases, mating skew decreases).

RESULTS

Preliminary Analyses

To ensure that hypothesis testing examined the relationship between the number of options and mating skew, rather than between the number of options and the number of offers (which was positive, and equally so, for men and women: $r_{116} = 0.87$, $P = 0.001$), we analysed how the total number of offers made in a session related to each skew measure. For three of the five measures, the number of offers made in a session was significantly, negatively related to mating skew: the more offers made in a session, the less skew (I_p yielded a significant, positive result). These findings led us to control for the number of offers in our hypothesis tests.

Furthermore, our preliminary analysis uncovered a sex difference in the average number of offers made in a session (independent t test: $t_{234} = -7.13$, $P = 0.001$, partial correlation (r_p) = -0.42) with women (coded $+1$) making significantly fewer offers ($\overline{X} \pm SD = 64.23 \pm 42.82$) than men (coded -1; 89.80 ± 60.67). Consequently, our hypothesis testing controlled for this sex difference, so that should any sex difference in the relationship between the number of options and mating skew arise, we could be sure that it was not due to the sex difference in the number of offers.

Hypothesis Testing

Each measure of mating skew was independently regressed on the choosing sex (coded as above), number of options (standardized as z scores), and their interaction, while simultaneously controlling for the number of offers made in the session (standardized as z scores) and the interaction between the choosing sex and the standardized number of offers. For the purposes of hypothesis testing, outliers were detected via the examination of Studentized deleted residuals, Leverage values and Cook's distance (with conservative thresholds outlined by Judd & McClelland 1989), and then removed so as not to have undue influence on the tests of the coefficients (see Table 1).

Table 1 presents the unstandardized regression coefficients, partial correlations and two-tailed significance levels of all coefficients for each of the five mating skew measures, as well as the number of outliers removed from each regression. As the intercept values indicate, for four of the five measures, the average skew was significantly different from and greater than 0. The one deviating result (S_c), while not significant, was also positive. Thus overall, offers were not randomly (nor evenly) spread across the options in each session, supporting the expected sexual selection-driven inequality in mating success.

Four of the five indices show that the choosing sex was related to the inequality of offers, with women's choices evincing more skew than men's choices. Again, while the one deviating result (I_p) was not significant, its sign was in the same direction as the others. Thus, these results are consistent with women being the choosier sex (Trivers 1972), showing that they differentiated among their mate options more than did men (as well as making fewer offers).

With respect to our main interest, the number of options available to choosers was significantly associated with all five mating skew measures, over and above the relationship between number of offers and mating skew, with four of these indicating that this relationship was positive (more options led to more skew) and only λ indicating a negative relationship (more options led to less skew). The weight of the evidence therefore suggests that the relationship between the number of options and mating skew among humans is positive: the more potential mates available to choose from, the more skewed the distribution of offers in speed-dating sessions (controlling for the number of offers). Furthermore, this relationship held for both men and women.

The discrepant finding observed with λ may be the result of that measure's insensitivity to true distributional differences in certain situations (e.g. in small groups with high productivity, that is, a large amount of potential benefits, or in large groups with low productivity) which may be because its calculation does not make an adjustment for random factors (although note that the latter is also true of S_3; Nonacs 2000). Furthermore, λ is the only one of the examined measures based on the assumption that mating success decreases geometrically with rank. Perhaps as a consequence, λ does not describe well the entire distribution of offers in the speed-dating sessions, especially at the top end. One instance of this is that as the proportion of all potential offers that were obtained by the top-ranking (rank = 1) individual(s) increased, which is indicative of increasing domination by the top rank over lower ranks, λ actually decreased (as did S_3). At the same time, with proportionately more 'ties' for rank = 1 (indicating less inequality at the very top), λ increased, whereas the other measures were negatively related to this proportion. The λ measure also did less well than all of the others in explaining the proportion of offers obtained by the individual(s) with rank = N, although at least the relationship was in the expected direction, such that increasing skew was associated with the bottom-ranking individual obtaining proportionately fewer of the available offers. Table 2 provides the correlations found between these and other indicators of offer distribution and the five skew measures.

Table 1
Partial correlations (and unstandardized regression coefficients/SEs) for predictors of the five mating skew indices

Predictor type	Predictor	Mating skew index (no. of outliers removed)				
		S_c (8)	S_3 (1)	I_p (5)	B (3)	λ (4)
Primary	Intercept	(0.025/0.016)	(0.32***/0.01)	(0.37***/0.02)	(0.02***/0.001)	(0.14***/0.004)
	Choosing sex (-1=M, $+1$=F)	0.14* (0.03/0.02)	0.23*** (0.04/0.01)	0.05 (0.02/0.02)	0.14* (0.003/0.001)	0.23*** (0.01/0.004)
	No. of options (standardized)	0.18** (0.06/0.02)	0.31*** (0.07/0.01)	0.24*** (0.10/0.03)	0.14* (0.004/0.002)	-0.16* (-0.01/0.005)
	Choosing sex* No. of options (standardized)	-0.1 (-0.02/0.02)	-0.02 (-0.01/0.01)	-0.06 (-0.03/0.03)	0.00 (0.00/0.00)	-0.05 (-0.004/0.005)
Covariate	No. of offers (standardized)	-0.14* (-0.05/0.03)	-0.39*** (-0.11/0.02)	-0.01 (-0.01/0.03)	-0.22* (-0.008/0.002)	-0.33*** (-0.03/0.01)
	Choosing sex* No. of offers (standardized)	-0.06(-0.03/0.03)	-0.15* (-0.04/0.02)	0.03 (0.02/0.03)	-0.11† (-0.004/0.002)	-0.17* (-0.02/0.01)

†$P < 0.10$; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Table 2
Simple correlations between the skew indices and other indicators of offer distribution

	Mating skew index				
	S_c	S_3	I_p	B	λ
Proportion of possible offers captured by option(s) at rank=1	0.01	−0.40***	0.18**	−0.04	−0.38***
Proportion of possible offers captured by option(s) at rank=N	−0.59***	−0.72***	−0.61***	−0.51***	−0.42***
Proportion of ties at option rank=1	−0.13†	−0.00	−0.29***	−0.17**	0.36***
Proportion of ties at option rank=N (even if N captured 0 offers)	0.13†	0.61***	−0.07	0.36***	0.72***
Proportion of options obtaining 0 benefits	0.57***	0.85***	0.17**	0.58***	0.79***

Option rank was determined by the number of offers received. If an individual received more offers than any of his/her competitors, then his/her rank = 1; if an individual received fewer offers than any of his/her competitors, then his/her rank = N. When there was more than one person at rank = 1, or rank = N, these constitute ties for the top and bottom rank, respectively (rows 3 and 4).
†$P < 0.10$; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

DISCUSSION

The theory of sexual selection maintains that an individual's probability of mating is nonrandom, such that 'high-quality' individuals will generally have more mating opportunities than will 'low-quality' individuals (Darwin 1874; Kokko et al. 1999). Research on animal mate choice has provided compelling evidence for this theory, as mating skew within the males of many species is greater than what is expected from random mating, and those males with the higher visit and copulation rates are typically (physically) dominant or in possession of elaborate ornamentation and, thus, higher in mate quality (Höglund & Alatalo 1995; Jennions & Petrie 1997; Constable et al. 2001; Alberts et al. 2003). In the present study, we sought to determine whether human mate choice, assessed via a structured and readily observable setting, also shows nonrandom skew. While it is already known from what people report (Buss & Barnes 1986; Buston & Emlen 2003) and what they do (Kurzban & Weeden 2005; Todd et al. 2007) that human mate choice is at least somewhat nonrandom (but see Lykken & Tellegen 1993), we wanted to test this further with a methodology similar to that used in the study of nonhuman animal mate choice. Our results show that mating skew is considerable among speed-daters: there was significant inequality in the number of offers received and, consequently, in the probability that a given individual would obtain a match (mutual offer) with another participant. This result was true for both sexes, but the inequality was greater among those individuals (men) being chosen by the choosier sex (women). Animal and human mate choice are thus both in line with this aspect of the theory of sexual selection.

Once nonrandomness was established, our main goal was to determine the effect of an increasing number of options on mating skew for speed-dating humans. Based on the pattern found for many animal species (Cowlishaw & Dunbar 1991; Widemo & Owens 1995; but see Charpentier et al. 2005), we expected, albeit with some reservation, that a larger number of options would result in less skew, so that the more minidates choosers had, the less choice consensus there would be on the 'top' mates (i.e. the less skew). This is not what we observed.

The weight of the evidence suggests that an increasingly large number of opposite-sex speed-daters brings about greater mating skew, so that top-ranking options dominate more and low-ranking options fare less well when they have more competitors. What factors may explain this surprising finding? Charpentier et al. (2005) also found a positive relationship between number of options and mating skew: as the number of competing male mandrills, *Mandrillus sphinx*, increased, the alpha male sired more offspring. They suggested that this positive result stems from increased competition among the subordinates in a larger group, which reduces their competition with the alpha male. This account, however, is irrelevant to the speed-dating context where direct between-dater competition is absent. This issue returns us to our

earlier proposal that human mate choice, especially in the speed-dating context, is relatively atypical among animals: some of the standard explanations for mating skew decreasing with the number of competitors, which primarily focus on the behaviour of the to-be-chosen, seem not to apply (e.g. the ability to influence the mating behaviour of competitors).

Instead, we focus on the behaviour of the choosers (Johnstone & Earn 1999; Luttbeg 2004). To explain why the relationship between the number of options and mating skew is positive among human speed-daters, we propose that choice strategy may be key. Humans are known to use different choice strategies and different cues when faced with small versus large choice assortments. In particular, with more options to select from, choosers switch from time-consuming compensatory strategies that examine and combine multiple cues, to more frugal noncompensatory choice strategies that examine few cues and do not make trade-offs among conflicting ones (e.g. Payne et al. 1993). In a study examining this proposition in human mate choice (Lenton & Stewart 2008), participants were more likely to have used noncompensatory choice strategies (e.g. 'elimination by aspects'; Tversky 1972) when faced with a large set (64) than a small set (4) of web-dating profiles (64). Conversely, they were more likely to have adopted a compensatory strategy (e.g. weighted averaging, see Payne et al. 1993) when selecting a potential mate from the small set than the large set of web-dating profiles. This ability to switch strategies is not necessarily a specific adaptation to mate choice, but may rather be an adaptive mechanism that can be applied more generally to an abundance of options in a variety of domains, from mates to food items to consumer goods.

We believe that participants in the larger (versus smaller) speed-dating sessions were also more likely to use non-compensatory selection strategies. It is this difference in choice strategy and corresponding cue use that could explain the difference in the distribution of offers made between small and large speed-dating sessions. The greater consensus regarding who was a high- and who was a low-ranking individual (and hence the greater skew) in larger sessions could indicate that participants in these sessions focused in a noncompensatory fashion on easy-to-observe cues that reflect preferences held in common by many people. In contrast, if participants in smaller sessions attempted to combine more cues in a compensatory manner, including those reflecting relatively idiosyncratic preferences, then the distribution of offers across individuals could have become more spread out and less skewed. Recent research shows that speed-daters largely pay attention to visually observable cues such as body mass index and physical attractiveness, about which people tend to possess a common notion of what makes for an appealing mate, and less so to harder-to-observe cues such as education level and desire for children (Kurzban & Weeden 2005). Although people report that such difficult-to-observe cues are among the most important traits in a long-term partner (Buss & Barnes 1986), it is of course tricky to

assess them and make use of them when speed dating, and it is likely to be even more challenging to assess and remember them in larger sessions, where there is more information to process. In contrast, humans automatically make holistic attractiveness judgements with a mere glance (less than 15 ms of exposure; Olson & Marshuetz 2005); thus speed-daters could readily have arrived at consensual judgements and subsequent choices using visual cues even when facing large option sets. To test more specifically whether this explanation holds, future research should track what information people seek and use in making their decisions at speed-dating sessions with different numbers of participants, for example by means of verbal protocols or other process-tracing techniques.

One question that remains is why nonhuman animals would not adjust their choice strategy in the same way when faced with small versus large option set sizes. Research suggests that nonhuman animals may indeed change strategy as a function of the size of the option set encountered. Bateson & Healy (2005) proposed that, like humans, other animals are likely to have evolved decision heuristics that depend on the number and quality of others with whom the potential mate is being compared. Similarly, Sullivan (1994) suggested that time constraints may lead females within a species to use quickly assessed morphological traits as mate choice cues, rather than time-intensive behavioural displays. Accordingly, nonhuman animals and humans may both emphasize quickly and easily assessed (QEA) characteristics when making choices from larger aggregations, a context in which there are likely to be greater cue assessment costs if the decision maker were to persist in using compensatory choice methods (Fawcett & Johnstone 2003).

If nonhuman animals and humans have this strategy-switching ability in common, then why do we find that the relationship between mating skew and option set size is positive for humans but (largely) negative for other animals? The answer may lie, at least in part, in the number of available QEA characteristics for our speed-daters compared to other species. Monogamous species appear to possess fewer display traits and secondary sex characteristics than lekking or polygamous species (Møller & Pomiankowski 1993; Candolin 2003). Thus, humans, being only mildly polygynous (Symons 1979), if not serially monogamous (Fisher 1989), may be more likely than other species to evaluate the same QEA characteristics across multiple potential mates. For example, speed-daters might only look at the potential mates' physical attractiveness, whereas female white-bearded manakins, *Manacus manacus* (family Pipridae) could assess the male's plumage ornamentation, the 'snapping' sound made by his wing feathers, his acrobatic display between the saplings and/or the protrusion of the male's beard (Snow 1962). When faced with many (versus few) potential mates then, female manakins may assess only one or two of these cues, and different individuals might assess different ones. Because such cues are not necessarily positively correlated (Candolin 2003), these females are more likely to make different choices and, hence, mating skew will be weaker with more options. Again, different individual humans, in contrast, may assess the same small number of cues, and be even more likely to do so when faced with a multitude of options, thereby ending up with more mating skew in those contexts.

Importantly, behavioural traits are more likely than morphological traits to explain choice among animals that typically mate in aggregations (Fiske et al. 1998). If a potential mate's behaviour (rather than physical appearance) is the primary cue under consideration, then options are more likely to seem different to different choosers. To illustrate, consider the results of a study of marine iguanas, *Amblyrhynchus cristatus* (Wikelski et al. 2001). The researchers observed that individual male marine iguanas varied within themselves in the degree to which they bobbed their heads in the presence of females. Female marine iguanas were more likely to mate with a male that head-bobbed in their presence. Thus, if choosers pay attention to behavioural cues that vary more in terms of what each chooser sees (compared with morphological cues, which will be more consistent across choosers), they are more likely to make different choices from one another, thus producing less mating skew. Again, speed-daters are known to favour morphological cues (e.g. body mass index, see Kurzban & Weeden 2005) and, thus, they are more likely to make the same choices as one another, thereby producing more mating skew when faced with a larger number of potential mates. To determine whether these explanations for the human results are plausible, however, future research should investigate the relationship between the number of options and mating skew in other relatively monogamous species (e.g. via the hidden lek hypothesis, Tarof et al. 2005).

Thus, while the relationship between mating skew and number of potential mates is different for humans and many nonhuman animals, we propose that the underlying choice process may be the same: both humans and nonhuman animals rely on easy and efficient cues to make their mate choices, especially when faced with many options; it is just that the type and quantity of cues they use may differ.

Acknowledgments

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