Fertility affects asymmetry detection not symmetry preference in assessments of 3D facial attractiveness

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Abstract

Consistent with theories from evolutionary psychology, facial symmetry correlates with attractiveness. Further, the preference for symmetrical faces appears to be affected by fertility in women. One limitation of previous research is that faces are often symmetrically lit front-views and so symmetry can be assessed using 2D pictorial information. Another limitation is that two-alternative-forced-choice (2afc) tasks are often used to assess symmetry preference and these cannot distinguish between differences in preference for symmetry and differences in ability of asymmetry detection. The current study used three tasks to assess the effects of facial symmetry: attractiveness ratings, 2afc preference and asymmetry detection. To break the link between 2D pictorial symmetry and facial symmetry, 3D computer generated heads were used with asymmetrical lighting and yaw rotation. Facial symmetry correlated with attractiveness even under more naturalistic viewing conditions. Path analysis indicates that the link between fertility and 2afc symmetry preference is mediated by asymmetry detection not increased preference for symmetry. The existing literature on symmetry preference and attractiveness is reinterpreted in terms of differences in asymmetry detection.

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Symmetry has for a long time been associated with attractiveness. According to Aristotle, “The chief forms of beauty are order, symmetry and definiteness” (*Metaphysica 13*). Darwin (1882) took the link between symmetry and beauty further and suggested that symmetry is a product of sexual selection. These speculations have continued and now there is a growing body of evidence that suggests that fluctuating asymmetry, which is measured as random bilateral deviations, (Van Valen, 1962) is related to attractiveness. The level of fluctuating asymmetries is thought to be an honest indicator of genetic quality. Among non-human animals, lower fluctuating asymmetry is associated with more successful mating (e.g. Møller, 1992, Manning & Chamberlain, 1993). In humans, lower levels of bodily fluctuating asymmetry are associated with a higher number of sexual partners (Thornhill & Gangestad, 1994). It would be likely, therefore, that fluctuating asymmetry in the human face would also be important in attractiveness and mating. This idea is underpinned by two premises. First, that facial symmetry can be detected in the natural viewing of faces. Second, that facial symmetry plays an important role in the mating process such that the size of the preference for symmetry changes between individuals and within individuals at different times. These two premises are evaluated here by looking at the detection and responses to symmetrical and asymmetrical faces.

Naturally occurring asymmetries

A number of studies have sought to assess the relationship between naturally occuring facial asymmetry and attractiveness. It has been demonstrated that where there is a high degree of asymmetry, for example as a result of chromosomal abnormality, this is associated with a decrease in attractiveness (see Thornhill & Møller, 1997). Studies that explore asymmetry at more typical (and non-pathological) levels have been mixed in their findings for the association between asymmetry and attractiveness. Some studies, usually assessing symmetry with 12 or 14 facial landmarks, have shown a positive relationship between attractiveness and symmetry (e.g., Jones, Little, Penton-Voak, Tiddeman, Burt & Perrett, 2001; Hume & Montgomerie, 2001; Scheib, Gangestad & Thornhill, 1999). More recent studies, that have used an assessment of asymmetry that employed more landmarks, have found a more limited correlations between asymmetry and attractiveness. One such study by Kaipainen, Sieber, Nada, Maal, Katsaros and Fudalej (2015) assessed the symmetry of 59 faces using 3D scans and found that attractiveness was not influenced by degree of symmetry. Another study by Farrera, Villaneuva, Quinto-Sanchez and Gonzalez-Jose (2014) used 28 facial landmarks on 565 faces to assess facial asymmetry. They found that the rated attractiveness of the faces did not significantly correlate with asymmetry of the faces.

Simmons, Rhodes, Peters & Koehler (2004) found that faces showed both fluctuating asymmetry and directional asymmetry. Directional asymmetry is the asymmetry within a group of organisms such that one side is consistently different to the other. They found that fluctuating asymmetry was related to attractiveness whereas directional asymmetry was not. One potential problem with this demonstration of directional asymmetry was that 2D photos were used. If the head position possessed any rotation then this would have appeared as asymmetry. Further, if people are consistently inclined to present a particular side of their face then with would show up as directional asymmetry.

The research using natural images has been inconclusive as to whether symmetry is related to attractiveness. Photo-manipulation, however, has proved to be an invaluable tool in revealing the relationship.

Symmetry-enhanced faces

A variety of methods for changing the symmetry of a face have been used. Initial studies, that constructed a face from a half face and its mirror reverse, did not find a symmetry advantage (Langlois, Roggman & Musselman, 1994). This was probably due to artefacts introduced by slight yaw rotation in the original image creating images unlike commonly encountered faces. Grammer and Thornhill (1994) found that blending faces together made for more symmetrical faces, which were more attractive beyond just their greater averageness. In other studies, symmetry was achieved by blending a whole face with its mirror reverse. Some of these show a link between symmetry and attractiveness (e.g., Rhodes, Proffitt, Grady & Sumich, 1998) but not all (see Swaddle and Cuthill, 1996).

The method of increasing asymmetry employed by Grammer and Thornhill (1994), Kowner (1996) and Rhodes and colleagues (1998) all involved the blending of faces with its mirror image. This method has the effect of making any asymmetries in the lighting conditions also more symmetrical. This can clearly be seen in second example of Figure 1 in

Rhodes et al. In that example, the starting face is lit slightly from the left-hand side. The resulting symmetrical face appears to be lit centrally. This method of generation of stimuli, therefore, confounds facial symmetry with symmetry of lighting conditions. Any observed preference for the symmetrical faces could, feasibly, be a preference for the symmetrical lighting conditions.

An alternative method of creating symmetrical faces is to average the facial structure from the left and right hand side of the face while keeping the original texture map. This is the method that was developed by Perrett, Burt, Penton-Voak, Lee, Rowland and Edwards (1999) and employed by Little and Jones (2006) and Little, Jones, Burt and Perrett (2007) amongst others. The resulting symmetrical faces, therefore, retained their texture based asymmetries. Any asymmetry in lighting conditions will remain in the symmetrical face. Any yaw rotation that is present in the original face, however, will be removed by this process meaning that the symmetrical face will always appear to be frontally oriented whereas the original face many have slight yaw rotations. Given that the original facial images were constructed under carefully controlled conditions, this potential yaw effect is likely to be minimal. Experiments that increase facial symmetry in this way, such as those mentioned above, consistently show an attractiveness preference for symmetrical faces over asymmetrical faces.

All of the methods described here for testing the effect of symmetry on attractiveness using photo-manipulated images confound 2D pictorial symmetry with 3D facial symmetry. The symmetrical face also occurs in a symmetrical image. An object can have 3D symmetry but produce an image that is asymmetrical – imagine a perfectly symmetrical face that is rotated away from the viewer. That face would have 3D symmetry but the projected image would not have 2D symmetry. It is not clear, therefore, whether the preference for symmetry is a preference for the symmetrical 2D image or the 3D symmetrical face. This confound has important theoretical implications. If the evolutionary explanation for the attractiveness preference for symmetry is to be meaningful then it is necessary that the preference is expressed for the 3D facial properties and not the 2D properties of the visual stimuli. Social interactions do not occur with heads exactly facing each other and with symmetrical lighting and so it is, firstly, important that symmetry can be extracted from more natural conditions. Secondly, it is important that this 3D symmetry relates to preference for faces. The current research aimed to resolves these issues by exploring the effects of changing the 3D symmetry of faces viewed in more natural asymmetrical conditions.

Testing the preference for symmetrical faces

There have been two main types of tasks employed to assess the link between facial symmetry and attractiveness. The first simply asking for attractiveness ratings of symmetrical and non-symmetrical faces. If there is a strong effect of symmetry on attractiveness then one would expect this to be apparent in the difference between attractiveness ratings given to symmetrical and asymmetrical faces. Simple ratings of attractiveness have been used to show that increasing the symmetry of a face produces higher ratings of attractiveness (Grammer and Thornhill. 1994; Langlois, Roggman & Musselman, 1994; Rhodes and colleagues, 1998, Rhodes. Yoshikawa, Clark, Lee, McKay and Akamatsu, 2001; Perrett and colleagues, 1999, Experiment 3; Little, 2014).

A commonly employed alternative to this task is to present images in pairs and ask which face is more attractive: the pairs of images differing only in their degree of symmetry. This two-alternative-forced-choice (2afc) method has become popular in assessing the preference for symmetry in faces and has demonstrated an attractiveness preference for symmetrical faces many times (e.g., Perrett and colleagues, 1999, Experiment 3; Vingilis-Jaremko & Maurer, 2013, Experiment 1; Little, Apicella & Marlowe, 2007; Little & Jones, 2012) and even with nonhuman primates (Waitt & Little, 2006). This method was used to show the symmetry preference was not present for inverted faces (Little & Jones, 2003). A slight variant of the symmetry-preference task involves asking the participant to provide a score as to how much more attractive one member of the pair is to the other as used by Quist, Watkins, Smith, Little, DeBruine and Jones (2012).

The 2afc symmetry preference task has been undoubtedly useful in determining the presence of a symmetry preference. Indeed, it has been used to assess differences between individuals in the degree to which they have a preference for symmetrical faces. It is argued that some people (or the same people but at different times) have a stronger symmetry preference than others and conclusions have been drawn about these differences. It is described later why some of these conclusions may be stretching the evidence but first these individual differences are described.

Individual differences in symmetry preference

The 2afc symmetry-preference task has been used widely to assess individual differences that might affect the link between symmetry and attractiveness. It has been hypothesised that there are reasons why some people may show a greater symmetry preference for attractiveness decisions for faces. These hypotheses are based on evolutionary psychology and suggest that symmetry is an indicator of good genes and immunocompetence (Thornhill & Gangestad, 1999) so some people, at some times, will value this feature more than others in a potential mate.

Individual differences in symmetry preference have been reported in diverse situations. Little, Apicella and Marlowe (2007) showed ethnicity differences with stronger symmetry preferences being shown by a group of Tanzanian hunter-gatherers than by Europeans. It was suggested that this was a consequence of a higher prevalence of pathogens in Tanzania than in Europe and so immunocompetence would be valued more. They also found that greater hunting ability in men correlated with an increased preference for symmetry in attractiveness decisions. It was argued that this is because these men could be choosier about their mates and so would value visual signals of good genes more than men who were poorer hunters. In European populations, sexual attitudes have been linked to the size of the symmetry preference. Quist and colleagues (2012) found that women with a positive attitude to uncommitted sex showed a larger preference for symmetry than women with a negative attitude to uncommitted sex. It was argued that women more likely to have uncommitted sex would be more interested in the gene quality of potential partners than their potential as caregivers. The symmetry preference can also be affected by pathogen priming. Little, DeBruine and Jones (2011) found that showing disease-related images prior to a symmetry-preference task increased the size of the symmetry preference. It was suggested that the pathogen priming cues the importance of immunocompetence in partners.

One important finding has been that the stage of the menstrual cycle can affect the size of the symmetry preference with women showing a stronger preference at times of higher fertility (Little, Jones, Burt & Perrett, 2007; Oinonen & Mazmanian, 2007). The explanation for this was that when conception was more likely, women would value traits that indicated good genes in a mate whereas when conception was unlikely the quality of the genes of the sexual partner was of little importance. This gene-optimisation-strategy explanation for the difference was further supported by the finding that the difference in the symmetry preference was larger when assessing faces as potential short-term partners rather than long-term partners (Little & Jones, 2012). The effect of fertility on symmetry preference, however, was not reproduced in a study by Cárdenas and Harris (2007) and this variation in results has been reviewed in meta-analyses. There has also been considerable discussion as to how valid measures of fertility are (Gangestad, Haselton, Welling, Gildersleeve, Pilsworth, Burriss, Larson & Puts, 2016) and whether they can be usefully linked to behavioural changes (Gonzales & Ferrer, 2016).

Two different meta-analyses have been conducted on the potential effects of fertility on symmetry preference. The first, by Wood, Kressel, Joshi and Louie (2014) found that while there was a robust increase in the size of symmetry preference at times of higher fertility, the effect of type of relationship (long term or short term) was not robust. The second and much larger meta-analysis, by Gildersleeve, Haselton and Fales (2014), found that the effect of fertility itself was not significant overall but analysis of data based on ratings for short-term relationships only hinted at there being a larger symmetry preference during times of higher conception risk. These meta-analyses, however, included some studies that did not use the 2afc symmetry-preference tasks and many such studies do not show a link between fertility and symmetry preference (e.g., Hromatko, Tadinac and Prizmic, 2006; Koehler, Rhodes and Simmons, 2002; Peters, Simmons and Rhodes, 2009).

Concerns have been raised about the use of 2afc tasks to assess preference for facial attractiveness features - although, this is usually within the context of preference for masculinity effects (Penton-Voak, 2011). Scott, Clark, Boothroyd and Penton-Voak (2013) describe a serious concern that the task may be directing participants to a trait that might otherwise be ignored.

One further concern, addressed in the current research, is that the 2afc designs do not necessarily capture differences in a preference for symmetrical faces. There is the possibility that differences in performance on 2afc tasks may reflect differences in the ability to detect the trait rather than a difference in the preference for the trait. A stronger preference for symmetrical faces may be more related to better visual processing of the images rather than any increased preference for images of one type. The current research explored this possibility by correlating individual performance on a 2afc symmetry preference task with the same individuals' differences in attractiveness ratings for symmetrical and asymmetrical faces and their ability in the detection of asymmetry in faces. In this was it was hoped to establish whether individual difference were being driven by attractiveness preference or visual ability. Menstrual cycle information was also collected to explore whether performance on any of the tasks correlated with fertility measures.

Experiment

The current study used a novel method to study facial symmetry making use of 3D face generation software. FaceGen 3.5 can generate photorealistic artificial faces in 3D. The shape and color-maps of these faces are derived from the statistically qualities of hundreds of 3D scans of human faces. From this software, it was possible to generate a set of test faces that each had a typical level of facial asymmetry and another set that were symmetrical. The lighting conditions and the yaw rotation could be controlled to ensure that any image asymmetry was a result of facial properties rather than viewing condition. Further, visual asymmetries could be introduced to the images by rotating the face or by lighting the faces from one side. In this way it was possible to assess the perception of facial asymmetry under more naturalistic viewing conditions.

One concern that could be raised about the current research is that computer-generated faces are being used as stimuli. There has been some concern as to whether such images are processed as real faces. However, Matheson and McMullen (2011) showed that FaceGen faces show similar psychological effects to real faces (i.e. own-race bias, inversion effects and an interaction between these effects). More recently it has been shown that the size of the own-race bias is reduced for computer-generated faces relative to real faces indicating that there are differences between them (Crookes, Ewing, Gildenhuys, Kloth, Hayward, Oxner, Pond & Rhodes, 2015). While this is a concern for the current research it is also a concern for previous research on facial symmetry. All of the experiments described above that tested a preference for facial symmetry involved some kind of computer manipulation of the original faces. As such, these were testing computer generated faces. In fact, some studies were more problematic as they were comparing computer-generated faces with the original faces and potentially introducing confounds. It is not possible to carry out research on facial symmetry without generating artificial faces but an advantage of the method used here is that it was possible to assess performance in more natural viewing conditions with slight rotation of the heads and asymmetrical lighting conditions.

To assess the relationship between facial symmetry and attractiveness, three different tasks were employed with the same set of participants. The first task was simply rating the attractiveness of the faces presented individually in a random order. This is similar to the tasks employed by Koehler, Rhodes and Simmons (2002). The second task was an attractiveness preference decision between two faces that varied only in their symmetry: a 2afc symmetry-preference task. Tasks of this nature have been used widely to examine differences in the preferences for symmetrical over asymmetrical faces (Little and Jones, 2012). The third task involved detecting whether each face was symmetrical or asymmetrical. Where detection of facial symmetry has been previously analysed, a 2afc design has been employed (e.g., Little & Jones 2006; Oinonen & Mazmanian, 2007). Here, the task involves the presentation of a single image and a decision concerning that image (more similar to studies that assess detection of symmetry in non-facial stimuli, e.g., Evans, Wenderoth & Cheng, 2000). This third task lacks the external validity of the other two tasks as it is not related to judgements of attractiveness: judging the symmetry of a face is not a task most people are called on to do in real world situations. The purpose of this task was to determine whether there were differences in the ability to detect that a face possessed an asymmetry rather than to make any decision as to its attractiveness.

The three tasks were assessed across participants and so participant individual differences could be assessed. This meant that links between the ability to detect facial symmetry and the assessment of attractiveness of symmetrical faces could be investigated. It also meant that the effect of the level of fertility of the participants could be investigated for each of the three tasks. This measure was included because there is a wealth of literature that shows that fertility changes over the menstrual cycle can change perceptions and cognitive abilities in general (e.g., Broverman, Vogel, Klaiber, Majcher, Shea & Paul, 1981; Hampson, 1990; Pearson & Lewis, 2007) and perceptions of facial symmetry in particular (e.g., Little, Jones, Burt & Perrett, 2007). In order to draw parallels between the current study and previous studies into the effects of fertility on facial symmetry, the exact same method of assessing fertility was used here as was employed in the second study reported by Little and colleagues.

Method

Participants

Eighty six undergraduates took part in the study for course credit. All were female and they were aged between 18 and 28 years old. The sample size was considerably smaller than has been suggested for between-participants studies looking at the effects of conception risk (see Gangestad, Haselton, Welling, Gildersleeve, Pilsworth, Burriss, Larson & Puts, 2016, or Gonzales & Ferrer, 2015). However, the primary aim of the current research was to explore individual differences between the tasks and relating these to conception risk was a secondary outcome. Little et al. (2007) showed an effect size of 0.5 for their fertility measure on the 2afc symmetry preference task and so 50 normally cycling participants were aimed for in the current experiment.

Stimuli

Facegen 3.5 software was used to generate all of the stimuli. An original set of 40 faces was generated using the randomiser with some fixed properties. The fixed properties were age set to 25, race set to European, gender set to male and a typical level of distinctiveness. The final fixed property was the asymmetry of the face, which was set to the typical asymmetry observed in the database. This is based on the asymmetry present in the faces used to construct FaceGen and so would contain both the fluctuating and any directional asymmetry (see Simmons, Rhodes, Peters & Koehler, 2004). A second set of 40 faces was generated from the first by reducing the level of asymmetry to zero. In this way, there were two matched sets of faces: one symmetrical and one with asymmetries.

The actual stimuli used in the experiments were generated by deriving images of the 80 faces in four conditions. These were factorially based on two levels of lighting and two levels of rotation. The lighting conditions were either *central* with a single light source above the viewer at an elevation of 45 degrees or *side* with a single light source with an azimuth of 45 degrees and an elevation of 45 degrees creating an asymmetrical pattern of shadows on the face. The levels of yaw rotation were either *frontal* or *rotated* 10 degrees to the right. This meant that there were 320 stimuli images in all. An example of a set of the stimulus images is shown in Figure 1. A further set of images based on six more randomisations were generated as introductory and practice images.

Procedure

Participants answered a series of questions concerning their menstrual cycle. These questions were: whether they were using an oral contreptive; whether they had a standard length of cycle, and how many days it was from the beginning of their last menstruation. Only normally cycling participants with regular cycles between 26 and 31 days were placed into the fertility categories. Following Little and colleagues (2007), participants were categorised as being in the high fertility group if they were on days 6 to 14 and low fertility group if they were on other days.

Following the questionnaire, participants completed three different tasks consecutively and always in the same order.

Task 1: Attractiveness ratings. After a practice phase with six images, participants were presented with the 320 stimuli individually and in a random order. Each image was presented until an attractiveness rating was given to the image and the next image was presented. The scale ranged from 1 (unattractive) to 9 (attractive). Participants were encouraged to rate the images relative to other images in the set. It was also explained to participants that every image they saw was unique so they should not try to remember what rating they gave to a similar face.

Task 2: Attractiveness preference. In this task, 320 pairs of faces were constructed from each of the stimuli and the one opposite to it on the symmetry measure (so there was always one symmetrical face and one asymmetrical one). After a practice phase, participants were presented with the pairs and had to indicate which member of the pair they saw as more attractive.

Task 3: Asymmetry detection. Again there was a practice phase and then the 320 stimuli were presented individually in a random order. This time the participants identified whether the face was symmetrical or not. It was stressed that it was the symmetry of the face rather than the symmetry of the image that they had to judge.

Results

Task 1. Attractiveness ratings. Two participants gave the same attractiveness response to all of the faces and so their scores are not included in the current analysis. The 320 test stimuli were categorised according to their symmetry, lighting and yaw (two levels of each). The average attractiveness for each of these eight conditions was found for each of the 84 participants and these are shown in Figure 2. A three-way ANOVA was carried out to investigate the difference between these averages. Symmetrical faces were seen as significantly more attractive than asymmetrical faces, $F(1,83) = 66.892$, $p < 0.001$. The side-lit faces were seen as significantly more attractive than the front-lit faces, $F(1,83) = 20.704$, $p < 0.001$. The rotated faces were seen as significantly more attractive than the frontal faces, $F(1,83) = 31.228$, $p < 0.001$. The interaction between asymmetry and lighting was significant, $F(1,83) = 5.852$, $p = 0.018$, as was the three-way interaction between asymmetry, lighting and rotation, $F(1,83) = 7.004$, $p = 0.010$. Analysis of the interactions shows that there was a symmetry advantage for attractiveness in all four viewing conditions, all t's(83) > 3.349, p's

< 0.001. The size of this advantage for symmetry was greatest for yaw-rotated, side-lit faces and this was significantly larger than for the other three conditions, F's(83) > 4.566, p's < 0.036 (as illustrated in Figure 2).

Task 2: Attractiveness preference. Pairs of faces that varied only on their symmetry were assessed for which on was more attractive. There were 320 pairs in all four categories of viewing (two levels of rotation and two levels of lighting). The number of times the symmetrical face was selected as being more attractive was calculated for each of the four conditions for each of the 86 participants (see Figure 3). Four, one-sample t-tests with a null hypothesis of 50:50 responding showed that each condition found a preference for symmetrical faces over asymmetrical faces, t's(85) < 8.806, p's < 0.001. A two-way ANOVA was conducted on these data. There was a near significant effect of lighting showing a stronger symmetry preference for frontally lit faces over side lit faces, $F(1,85) = 3.609$, $p = 0.061$. There was a significant effect of yaw rotation showing a stronger symmetry preference for front-view faces over rotated faces, $F(1,85) = 14.848$, $p < 0.001$. There was also a significant interaction, $F(1,85) = 9.197$, $p = 0.003$. Analysis of the interaction found that symmetry preference for front-view, centrally lit faces was significantly stronger than in the other three viewing conditions, t's(85) > 3.129, p's < 0.002.

Task 3: Asymmetry detection. Two participants did not complete this task and so their data are not analysed (one failed to follow the instructions correctly and the other withdrew from the experiment). The performance of detecting asymmetry in the four different viewing conditions for the participants was assessed using signal detection theory. This process used the number of times that asymmetry was correctly detected out of a possible 40 items as well as the number of times that asymmetry was incorrectly reported out of a possible 40 items. The resulting discrimination (d') measure indicates how well the participant can detect asymmetry in each of the conditions irrespective of any response bias, which can also be recorded (see Figure 4). A two-way ANOVA was conducted on the discrimination of asymmetry. There was a significant effect of lighting showing better asymmetry detection for frontally lit faces over side-lit faces, $F(1,83) = 35.05$, $p < 0.001$. There was a significant effect of yaw rotation showing better asymmetry detection for front-view faces over rotated faces $F(1,83) = 56.65$, $p < 0.001$. There was also a significant interaction, $F(1,45) = 30.41$, $p < 0.001$. Analysis of the interaction found that asymmetry detection for front-view, front-lit faces was significantly better than in the other three conditions, t's(83) > 7.585, p's < 0.001.

The response bias, or criterion, was also analysed with a two-way ANOVA. A higher response bias indicates that the participant is more likely to select that the faces are asymmetric. The response bias was significantly larger for side-lit faces than for centrally lit faces, $F(1,83) = 72.766$, $p < 0.001$. Yaw rotation did not have a main effect on response bias, $F(1,83) = 1.721$, $p = 0.193$. The interaction was significant, $F(1,83) = 57.493$, $p < 0.001$, showing a larger effect of lighting for frontal faces than for yaw-rotated faces, although the effect of lighting was significant for both front views, $t(83) = 9.136$, $p < 0.001$, and yaw-rotated views, $t(83) = 4.541$, $p < 0.001$.

Individual differences analysis. Individual differences were assessed over the three tasks and, if the participants could be categorised, whether they were at a fertile or infertile stage of their menstrual cycle. From Task 1, a difference in the ratings given to symmetrical faces compared to asymmetrical faces was obtained for each participant. From Task 2, the total proportion of times the symmetrical face was selected over all stimuli pairs was obtained. From Task 3, the average asymmetry discrimination score over all stimuli was obtained. A fertility analysis was only conducted on female participants who were not taking the oral contraceptive pill and had regular menstrual cycles typically between 26 and 31 days in length: fifty of the participants. To ensure effective comparison, the menstrual cycle analysis used an identical classification to that employed by Little and colleagues (2007, Study 2). Like in Little and colleagues, the cycle day of each member of the two groups was translated into conception risk using the data from Wilcox, Dunson, Weinberg, Trussell and Baird (2001). The two groups showed a significant difference in their conception risk, $t(48) = 5.322$, $p < 0.001$. A secondary analysis is also presented in which the actual conception risk data form Wilcox and colleagues are used as a fertility variable in the correlations.

The correlations between the performance in the three tasks, fertility using the Little and colleagues categorisation measure and fertility based on conception risk are shown in Table 1. Performance in the three tasks all significantly correlated with each other although the larger correlation was between Tasks 2 and Task 3. The fertility category correlated significantly with performance in Task 2 and Task 3 although the conception-risk measure only correlated with performance in Task 3.

A path analysis was performed to assess the process by which the Little at al. (2007) fertility category might exert its influence on the 2afc symmetry-preference task (based on the 50 participants who completed all tasks and had a fertility score). The theoretical model being tested was that the effect of fertility on 2afc symmetry preference was either: being mediated by an increase in an attractiveness preference for symmetry (as would be shown in Task 1); being mediated by an increase in the ability to detect asymmetry (as would be shown in Task 3); or a direct effect. The path analysis (Figure 4) found that the link between fertility and performance on the 2afc symmetry-preference task was significantly mediated by asymmetry detection. All other pathways were not significant.

Discussion

The current research had two main aims. First, it aimed to assess whether the link between symmetry and facial attractiveness was driven by 2D image properties. Second, the research aimed to investigate what can be concluded from differences in 2afc symmetry preference differences. These issues are discussed, as is an unexpected finding related to facial attractiveness in portraits.

With regards to the first aim, the results of Task 1 clearly demonstrated that the symmetrical faces were rated as being more attractive than faces with a typical level of asymmetry. This finding is consistent with other research that assessed 2D symmetry (e.g., Grammer and Thornhill, 1994; Rhodes and Colleagues, 1998). What is new about this current finding is that it demonstrates that the attractiveness advantage for symmetrical faces is present even when faces are lit from the side or are rotated by 10 degrees yaw. These changes both mean that the symmetry of the image is not related to the symmetry of the face and so the increase in attractiveness ratings for symmetrical faces reflects a real preference for 3D symmetry and not just for 2D symmetry. This means that the associations between facial symmetry and attractiveness found in previous studies are not just an artefact of the symmetrical faces being presented in 2D images that were more symmetrical. In fact, the 3D symmetry advantage is greatest when the 2D symmetry is lowest. This finding is also important for evolutionary theories behind the link between symmetry and attractiveness because it means that facial symmetry affects attractiveness even under natural viewing conditions, which is necessary if facial symmetry is to have any real effect on mate selection or evolution.

Task 2 demonstrated that there was a consistent preference for the symmetrical face over an asymmetrical version of it when asked which face was more attractive in a 2afc design. This type of task is commonly employed in experiments exploring the relationships between attractiveness and symmetry (e.g. Little and Jones, 2012). This preference shown for symmetrical faces was strongest for front-view centrally lit faces. Transformations that disrupt the 2D pictorial symmetry of the image reduced this preference for 3D symmetry in faces but did not remove it altogether. The differences between the viewing conditions in this task is in contrast to that in the attractiveness ratings of Task 1 where the greatest effect of symmetry occurred when 2D symmetry was reduced the most. The differences between the pattern of results of Task 1 and Task 2 suggest that the two tasks are assessing different properties of the perception of the images.

Task 3 assessed the ability to determine whether a face was symmetrical or not. This task is independent of any assessment of attractiveness. The ability to detect an asymmetry was greatest when faces were front view and centrally lit – that is, when 2D symmetry could be used to assess 3D symmetry. Any deviation that disrupted the link between 2D symmetry and 3D symmetry reduced the discrimination of asymmetry. The conclusions from Task 3, therefore, are that 3D symmetry can be inferred in the absence of 2D symmetry but it is easier to detect it when there is also 2D symmetry. Analysis of the response bias suggests that there is a bias towards saying that faces are symmetrical in the front-view centrally lit condition and this is changed towards a bias to saying a face is asymmetrical when the 2D image is made more asymmetrical by lighting or rotation.

The pattern of data over the three tasks shows that there are at least two elements to judgements concerning facial symmetry. First, there is the enhancement that facial symmetry has on attractiveness judgements. This advantage occurs over all four viewing conditions but is greatest for side-lit yaw-rotated faces. Second, there is the ability to detect asymmetry in faces. This ability is present in all four viewing conditions but is greatest for front-view frontally lit faces. The attractiveness preference for symmetrical preference (Task 2) follows the pattern (strongest preference for front-view centrally-lit images) of results of asymmetry detection (Task 3) rather than attractiveness judgements (Task1 – strongest difference for rotated-view side-lit faces). The conclusion, therefore, is that 2afc symmetry preference in attractiveness judgements is affected more by asymmetry detection than by the size of the symmetry effect on attractiveness. This has important implications for those studies that have employed the attractiveness preference task to assess preference for symmetry. From the results discussed so far, 2afc symmetry-preference tasks appear to be assessing the ability to detect asymmetry rather than an evaluation of a person's preference for symmetry.

In order to further evaluate and interpret the 2afc symmetry-preference task, the data across the three tasks were assessed in terms of participants' individual differences in performance. There was a significant correlation between the symmetry-preference task and the differences between the attractiveness ratings for symmetrical faces and asymmetrical faces. This suggests that the 2afc preference task is related to a degree with the size of the preference for symmetrical faces. However, the correlation between the symmetry-preference task and asymmetry discrimination is stronger suggesting that the ability of a participant to detect asymmetry is an important determinant of the size of the attractiveness preference for symmetrical faces in the 2afc task.

Analysis of the individual differences in the participants' fertility data yields interesting findings. For the 50 normally cycling participants, those with higher levels of fertility performed better on the asymmetry-detection task than those with lower levels of fertility. The path analysis demonstrated that the previously observed finding that fertility correlated with 2afc symmetry preference (e.g., Little & Jones, 2012) is mediated by better detection of asymmetries. The observed changes in performance in the symmetry preference task may be a result of improved cognitive ability at the task rather than being an actual increase in the level of preference for symmetrical faces.

The results of Task 1 demonstrated an unexpected finding. The results show that transformations that reduce the 2D symmetry of the image, in fact, increase the attractiveness of the face. This may seem surprising to some vision scientists because greater 2D symmetry is usual interpreted as being more attractive; however, it is unlikely to surprise portrait artists. Throughout history, portrait artists and photographers tend to create 2D asymmetries using yaw rotation (consider da Vinci's *Mona Lisa*), lighting (consider Gainsborough's *The Blue Boy*) or both (consider Vermeer's *Girl with a Pearl Earring*) most likely in an attempt to enhance the attractiveness of the sitter (see an analysis by McManus and Humphrey, 1973). The current research shows that this enhancement is not due to the loss of 3D asymmetry information as it appears even when the faces are completely symmetrical. A speculative explanation for this finding is that the asymmetrical 2D views appear more naturalistic and therefore shows more warmth than the front-view centrally lit images that are more often associated with passports and police mugshots. Of course, one notable exception is Holbein's *Anne of Cleves* but it can be left to historians to determine why the artist chose an almost symmetrically lit front view of his sitter in this case.

Conclusion

The current experiment employed three tasks and an assessment of fertility to explore the role that symmetry plays in facial attractiveness. The results clearly demonstrate that perfect symmetry is preferred to the typical level of asymmetry observed in faces. This preference is not due to the 2D visual properties of the images but can be extracted from the 3D interpretations of heads. Hence, symmetry can be extracted efficiently under non-ideal viewing conditions and so could be evolutionarily significant in mate selection.

The research also demonstrates that many of the differences in preferences for symmetry observed using 2afc designs are a result of differences in the ability to detect asymmetry rather than a difference in a preference for symmetry. It is necessary, therefore, to revisit the individual differences that have been observed in the 2afc symmetry-preference task and re-interpret their meanings. We can no longer explain these differences in terms of differences in preference for symmetrical mates. Rather, the differences need to be explained in terms of differences in the ability to detect the asymmetry in faces.

Some of these the observed effects on the size of symmetry preference can be easily reinterpreted in terms of asymmetry detection; however, some require a little speculation. The loss of a symmetry preference for inverted faces (Little & Jones, 2003, 2006), for example, is easy to explain in terms of asymmetry detection. This effect simply reflects a loss of the ability to detect asymmetry as a direct consequence of loss of face processing skills that are specialised for upright faces. The effect that fertility has on the preference for symmetrical faces can also be interpreted as fertility affecting the detection of asymmetry. This proposition is supported by the fact that cognitive and visual abilities vary over the menstrual cycle (e.g., Broverman, Vogel, Klaiber, Majcher, Shea & Paul, 1981) and so it appears that the detection of asymmetries in faces is just another task that is so affected. The supposed increased preference for symmetrical faces observed at times of higher fertility (Little, Jones, Burt & Perrett, 2007) might just be a reflection of these improved cognitive abilities. This is consistent with studies that use attractiveness ratings not finding an effect of fertility (e.g., Koehler et al., 2002). The ethnic differences on the size of the symmetry preference can be re-evaluated. Tanzanian hunter-gatherers show a larger preference for symmetrical faces than Europeans (Little, Apicella & Marlowe, 2007), and this could be showing us that this group see less facial imagery than the European group and so pay more attention during the novel experiment. Little, Apicella and Marlowe (2007) also showed that better hunters within that community showed a stronger preference for symmetry than poorer hunters did. This finding might simply reflect the better hunters' superior visual abilities or attentional abilities, which would be useful both in hunting and in detecting an asymmetry in a face. The fact that pathogen priming increases the symmetry preference (Little, DeBruine & Jones, 2011) may reflect a heightened level of general vigilance and hence better asymmetry detection rather than an increased preference for symmetry. The link between symmetry preference and sociosexual attitudes (Quist et al. 2012) may have little to do with mate preference but more to do with some people having better face processing skills and these also being the people who have developed positive attitudes to having multiple sexual partners. One possible mechanism could be variations in oxytocin levels where higher levels of this hormone are associated with better face processing skills (e.g., Shahrestani, Kemp & Guastella, 2013) and also stronger sexual desires and behaviours (e.g., Veening, Jong, Waldinger, Korte & Olivier, 2014). Overall, the variations that have been reported in symmetry preference can be explained in terms of differences in the ability to detect asymmetries. Some of these explanations require a little speculation but so too did the explanations based on varying symmetry preference. For example, it was speculation that a women with lower fertility would rather mate with a person with a man with lower genetic quality.

In summary, the present research shows that there is an association between 3D symmetry and facial attractiveness. This link goes beyond just being a result of the additional fluency of processing a 2D symmetrical image and confirms that facial symmetry can be detected in natural views. Care needs to be taken, however, when designing tools that assess differences in the size of this association across conditions. Evidence that has been used to suggest that there are difference in the size of the preference for symmetry between individuals or within indivduals at different times may have more to do with differences in the ability to detect asymmetry than with differences in the degree of preference for symmetry.

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Table 1. Correlations (and point-biserial correlations) between participants' scores over the three tasks and the fertility measure.

		Task 1: Difference in attractiveness ratings	Task 2: Attractiveness preference	Task 3: Asymmetry discrimination
Task 2: Attractiveness	*r* =	0.334		
preference	*p* =	0.002		
Task 3: Asymmetry	*r* =	0.312	0.475	
discrimination	*p* =	0.004	< .001	
Little et al.'s (2007)	*r* =	0.089	0.284	0.404
Fertility categories	*p* =	0.541	0.046	0.004
Conception Risk from	*r* =	0.047	0.173	0.362
Wilcox et al. (2001)	*p* =	0.745	0.230	0.010

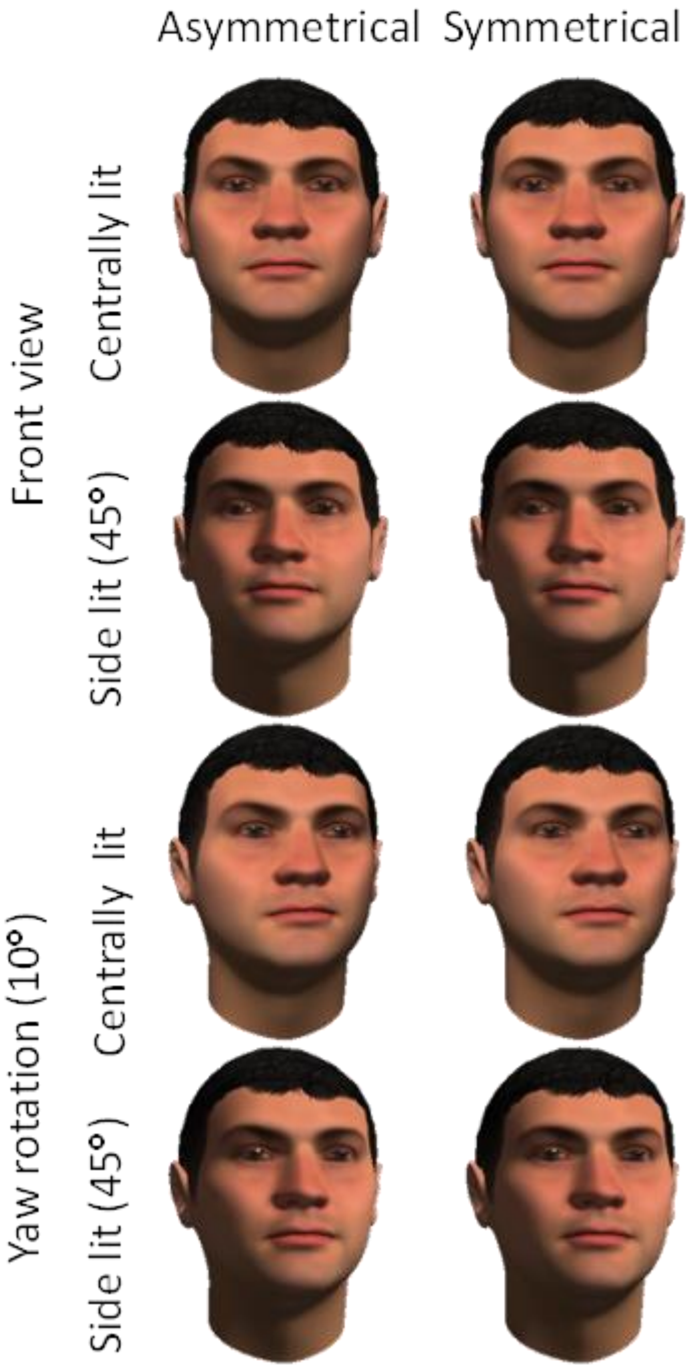

Figure 1. An example of the set of stimuli used in the three tasks. The left hand faces show the typically asymmetrical faces whereas the right hand faces have 3D symmetry. The top four images are front views whereas the bottom four faces are rotated by 10 degrees. The first and the third row are lit from the centre whereas the second and fourth rows are lit from the side. Color versions are available online.

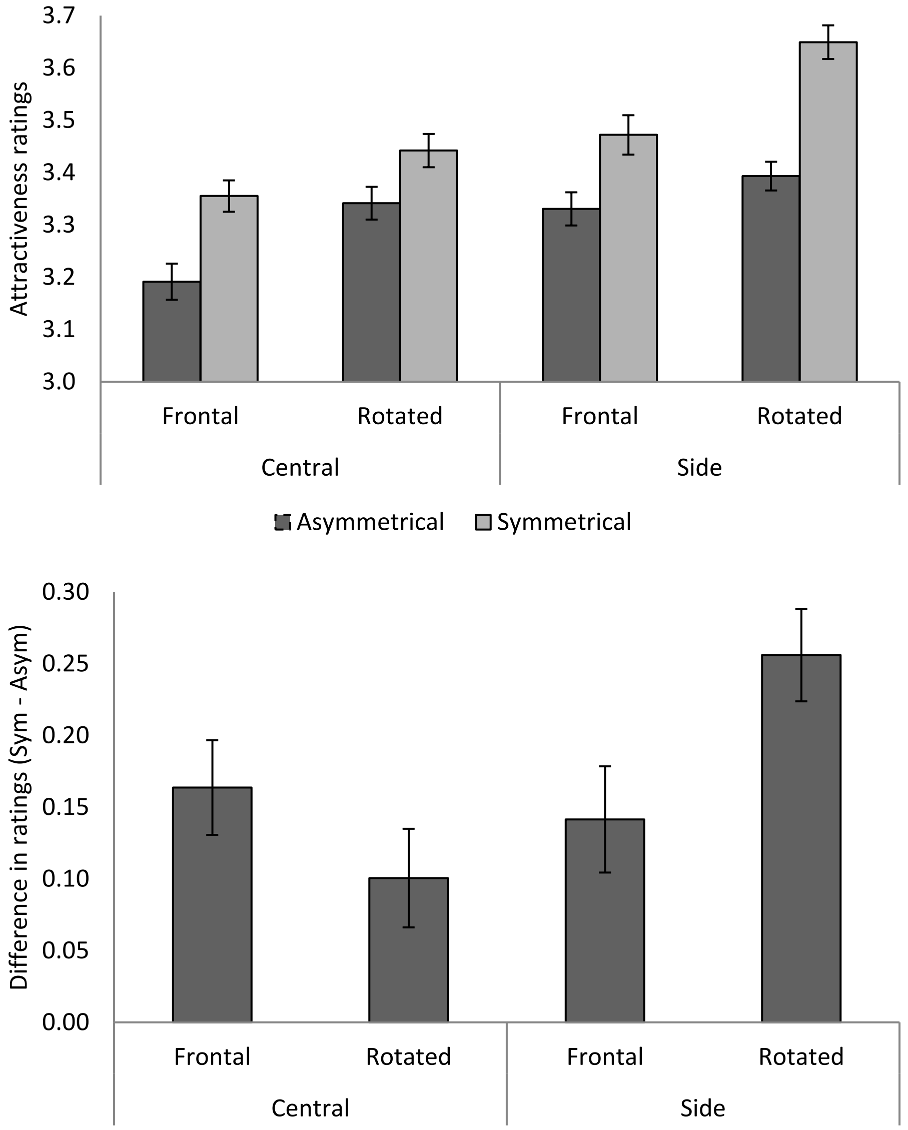

Figure 2. The average attractiveness ratings from Task 1. The top panel shows the actual scores given to the faces. The data are split according to the orientation of the faces (frontal or rotated 10 degrees in the yaw direction) and the lighting conditions (centrally lit or side lit). The bottom panel shows the differences between ratings for symmetrical and asymmetrical faces. All error bars show +/- one standard error.

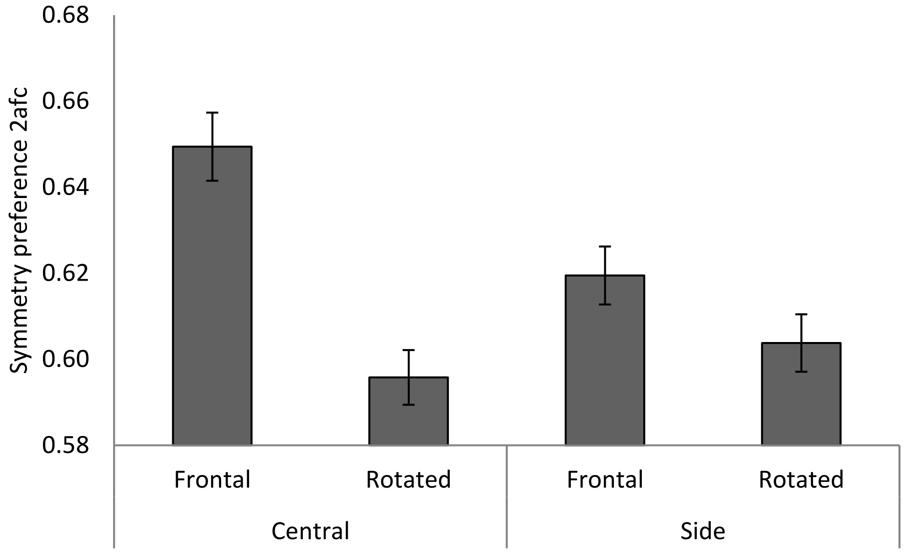

Figure 3. The average proportion of times that the symmetrical face was chosen from the face pairs in Task 2. The data are split according to the orientation of the faces (frontal or rotated 10 degrees in the yaw direction) and the lighting conditions (centrally lit or side lit). All error bars show +/- one standard error.

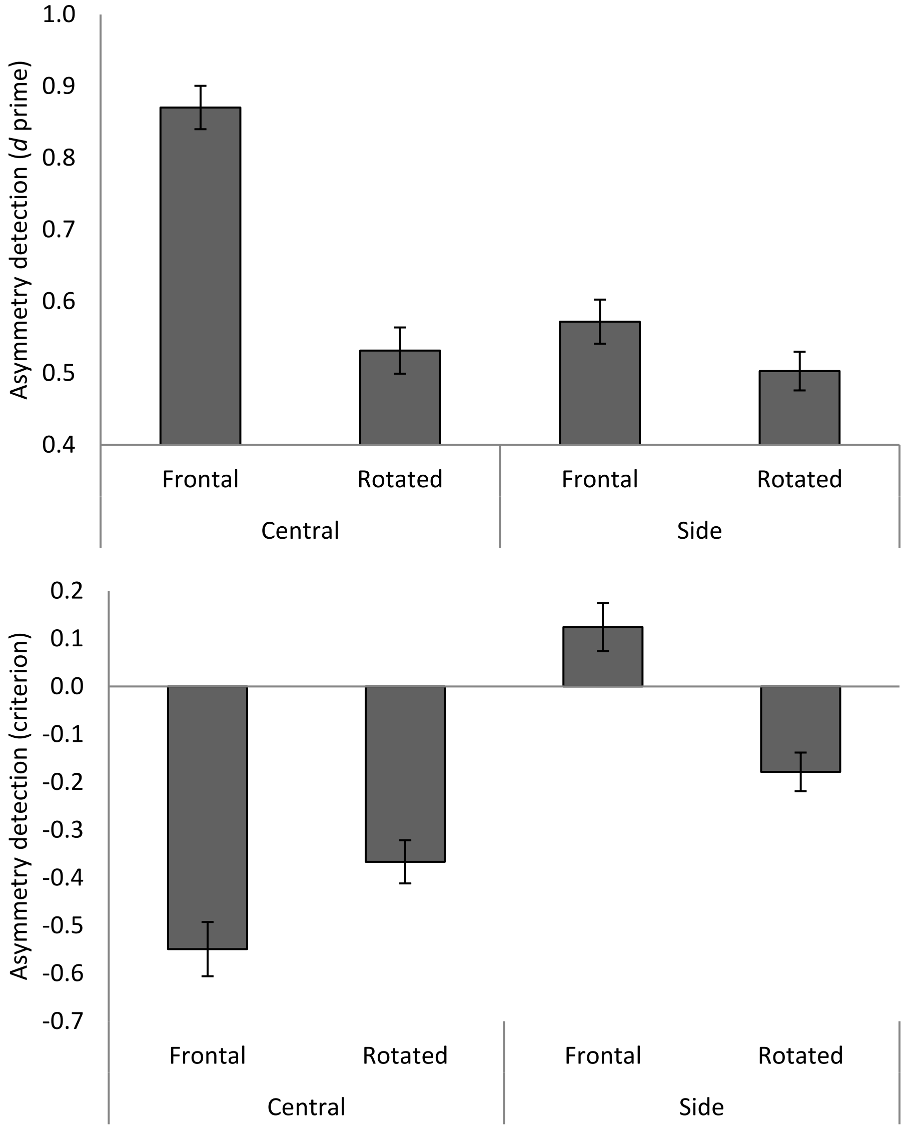

Figure 4. The discrimination (top panel) and response bias (bottom panel) based on analysis of asymmetry detection in Task 3. The data are split according to the orientation of the faces (frontal or rotated 10 degrees in the yaw direction) and the lighting conditions (centrally lit or side lit). All error bars show +/- one standard error.

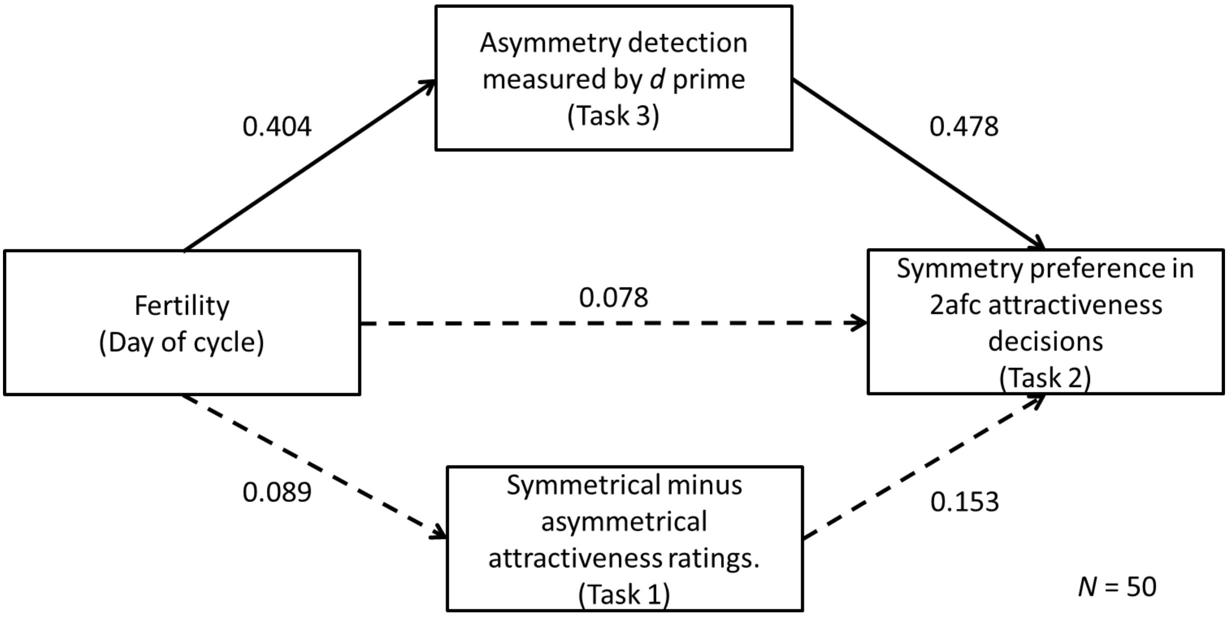

Figure 5. A path analysis of the three tasks and the fertility category for 50 normally cycling participants. The association observed between 2afc symmetry preference task and fertility (direct r = 0.284) is mediated by performance on the asymmetry detection task. Numbers show standardised coefficients. Solid arrows show significant paths, $p < 0.05$, whereas dashed lines show non-significant paths, $p > 0.05$.