SUMMARY
This article aims to outline the differences between men and women in cognitive strategies applied in mental rotation task. Mental rotation is recognised among the fundamental processes of spatial thinking. Good ability to assess the spatial relations between oneself and the surrounding makes it possible to take decisions quickly and to act effectively. Mental rotation tasks can be performed in various ways, depending on their type, and with a use of different cognitive strategies. The study explores characteristics of mental rotation task performance specific to women and men. The differences observed in this area are determined by multiple factors. It was pointed out that interactions between biological and environmental factors are of major importance for effective performance in mental rotation tasks. The discussion also focuses on task characteristics possibly determining different results achieved by men and women, and potentially affecting the choice of specific strategies applied in mental rotation tasks. Subsequently, the article reviews the evidence suggesting differences in cognitive strategies used during mental rotation tasks by women and men. It is also pointed out that, in the context of the observed sex-related differences, the type of strategies used are associated with methods of assessing visuospatial material and with task characteristics. The final part presents data from neuroimaging studies investigating brain activity recorded during performance of this type of tasks. The evidence was discussed with reference to sex differences in cognitive strategies applied in mental rotation tasks.

Key words: sex differences, brain activity, performance factors, mental rotation
240INTRODUCTION

Mental rotations are typical transformation processes engaged in human cognitive activity. The sequence of operations leading to mental rotation starts with extraction of features, recognition and determination of the spatial orientation of the object and leads to identification of the method of rotation to a typical position and to performing spatial mental transformation (Milivojevic et al., 2011). It is likely that transformation of a visual figure into a supramodal form is a precondition for executing mental rotation; this way the cognitive system is able to work out the spatial characteristics of the object, enabling its mental rotation irrespective of the sensory modality (Jancke et al., 2000). Effective processing and analysis of the spatial relations between the observer and the objects in his/her environment makes it possible for the former to take decisions quickly and to act with precision (Trojano et al., 2002). Assessment of abilities reflected by mental rotation task performance is recognised as a key element in research investigating individual differences in spatial abilities essential to many practical activities. Mental rotations are considered among the fundamental processes of spatial thinking (Terlecki et al., 2008). The use of visual imagery and mental manipulations in therapy designed for patients with various dysfunctions, of both motor and cognitive nature, is a promising approach to interventions applied for the purpose of neuropsychological rehabilitation.

There is a long history of research focusing on various aspects of differences in performance of cognitive tasks between men and women. The findings concerning sex differences in mental rotation are not unanimous. Most researchers report that men present greater capacities in this area (Hyde, 2007; Levine et al., 2016), however according to some studies there are no sex related advantages (Cohen et al., 1996; Tagaris et al., 1997; Beste et al., 2010; Toth & Campbell, 2019). In other studies, the groups are homogenous as regards the relevant variable, and the research focuses either on men or women which makes it impossible to make comparisons (Ecker et al., 2006). The factors potentially impacting the results achieved by men and women include the subject's characteristics, i.e., his/her cognitive style, individual differences in habitual spatial thinking, as well as the task characteristics, i.e., limited time for task performance, features of the stimulus subjected to rotation, the degree of its complexity (men seem to present an advantage if the rotated stimuli are more complex), rotation angle and the type of instruction in the task. Hence, sex is only one among a number of significant factors explaining differences in mental rotation performance (Bilge & Taylor, 2017; Levine et al., 2016). Some recent studies present evidence suggesting that the size of sex differences, as they were identified and reported in earlier publications, may be moderated by the aforementioned factors, such as task characteristics and performance factors (Toth & Campbell, 2019).

This study aims to outline the differences between men and women in mental rotation task performance and the determinants of these differences. The considerations mainly focus on the specificity and diversity of strategies applied by
FACTORS DETERMINING THE DIFFERENCES IN PERFORMANCE OF MENTAL ROTATION TASKS

The observed differences between women and men in mental rotation abilities may be linked to various causes. It has been suggested there are two groups of factors: biological (mainly differences in androgen levels, and differences in brain activity patterns during performance of mental rotation tasks), and environmental (e.g., stimulation and experiences typical for different sexes). Research findings report effects of testosterone as a hormone significantly contributing to the differences in performance of mental rotation tasks by women and men. Higher level of testosterone is linked to greater effectiveness in mental rotation tasks (Hooven et al., 2004). Many researchers have also pointed to the importance of emotional and motivational variables which may result from both biological and environmental factors (Parsons et al., 2004; Tomasino & Rumiati, 2004; Estes & Felker, 2012; Sharma et al., 2018; Oshiyama et al., 2018).

Considerations related to effectiveness in mental rotation tasks should take into account interactions between biological and environmental factors, because this way it is possible to more fully understand the determinants of differences observed in performance of this type of tasks. Better rotation abilities are shown by individuals whose experience includes multiple factors supporting spatial thinking. These include both biological determinants and the contemporaneous environmental experiences. These are associated with frequently taken actions which engage spatial thinking in course of problem solving. They also include social relations which do not strengthen the stereotypical schemas related to thinking about spatial abilities of men and women (Sanchis-Segura et al., 2018). With regard to environmental factors, it should be pointed out that, compared to women, most men in their daily activities are more likely to deal with tasks involving spatial transformations, which results in their greater experience and skill in performing this type of mental activity (Quaiser-Pohl et al., 2006). The types of activity suggested to boys more effectively contribute to development of spatial thinking compared to the activities typically intended for girls. Nevertheless, owing to diverse and rich environmental stimulation girls may also achieve high skills in this area. Evidence showing that development of spatial abilities results from experience comes from studies in which women achieved higher rate of spatial skill development than men after they had received a training with the use of a specific type of video games (Feng et al., 2007). Hence, with a specific combination of factors, women achieve similar results to those presented by men in mental rotation tasks (Christie et al., 2013), and sex as a biological factor is
not the only determinant for the skills shown. However, it should be emphasised that the favourable pattern of biological factors typical for men, combined with the desirable environmental impacts, may contribute to the development of high-level abilities in spatial thinking, which to a degree is reflected by the findings of studies focusing on sex-related differences in mental rotation (Levine et al., 2016).

**SEX DIFFERENCES IN PERFORMANCE OF MENTAL ROTATION TASKS**

The differences in mental rotation task performance reported by researchers are primarily reflected by greater speed and accuracy achieved by men (Parsons et al., 2004; Titz et al., 2010; Boone & Hegarty, 2017; Christie et al., 2013; Mochizuki et al., 2019), although some studies suggest faster performance of mental rotation tasks by women (Moë, 2009; Thomsen et al., 2000), and comparable effects with regard to accuracy (Voyer & Bryden, 1990). Better performance in this type of tasks shown by men compared to women seems to be related to such factors as the type of stimulus and the size of rotation angle. The most visible differences are found when three-dimensional figures or rotation angle exceeding 90 degrees are applied. Generally, the rotation angle exceeding 90 degrees is connected with longer reaction time both in men and women (Jansen & Heil, 2010). It suggests that complexity of the stimulus significantly impacts effectiveness of mental rotations, also making it possible to more clearly observe the differences between women and men (Bilge & Taylor, 2017). Women were also outperformed by men in these tasks when two-dimensional shapes, as well as real objects such as animals or tools were used, but the effect sizes were smaller (Collins & Kimura, 1997; Christie et al., 2013). Research evidence suggests that women more slowly transform 2D images into three-dimensional representations (Voyer & Doyle, 2010), however they also tend to be more accurate if the task involves rotation of real objects or body parts, such as hands (Neubauer et al., 2010; com. Toth & Campbell, 2019). In the tasks asking for mental rotation of hand image, where participants can see pictures or line drawings of hand at different angles, and are asked to decide whether left or right hand is displayed (Mochizuki et al., 2019), the findings did not always show that sex was related to accuracy of the responses. The studies also reported different reaction times. Some of them demonstrated that women needed less time to complete the task (Seurinck et al., 2004), and others reported shorter performance time in the case of men (Karadi et al., 1999).

Differences in mental rotation task performance, apart from the activity of rotation itself, may also be associated with the processes involved in solving such tasks, e.g., encoding the stimulus to be rotated as well as decision processes (Levine et al., 2016). Mochizuki et al. (2019) claim that images presenting complicated hand shapes are a type of stimuli which may reveal differences between men and women. The size of the observed differences may also be determined by the instruction accompanying the task. If it does not specify the need to apply
spatial thinking, the results show smaller differences between women and men in the parameters of the task performance (Scali et al., 2000). Research carried out nowadays emphasizes the importance of one's self-perceived abilities in spatial thinking. Campbell et al. (2018) demonstrated that women with high level of confidence in their ability to perform mental rotation realized the tasks in a similar way as men (cf. Toth & Campbell, 2019).

COGNITIVE STRATEGIES APPLIED BY WOMEN AND MEN IN MENTAL ROTATION TASKS

The factors affecting one's performance in mental rotation tasks include the type of strategy adopted for this purpose. Research in mental rotation investigates various cognitive strategies applied by subjects in order to perform tasks of this type. Some of these involve mental change of the observer’s perspective or mental rotation of the object itself (Voyer & Jansen, 2017), others are associated with the use of piecemeal or holistic strategies or approaches based on simulation of movement (Hegarty, 2018), yet other cases involve a leaping (match-jump) strategy or a more cautious approach (Hirnstein et al., 2009). Only some of them require rotation of the object to be performed. Therefore, when considering sex differences in mental rotation it is important to distinguish between conclusions related to solving of mental rotation tasks and those pertaining to the use of mental rotations in the process of completing the tasks. It turns out that subjects do not always mentally rotate the object. Sometimes they refer to other strategies. One might ask whether the differences between men and women identified in rotation task performance are indeed related to the activity of mental rotation, or perhaps they result from the varied abilities to apply other strategies in coping with mental rotation tasks (Boone & Hegarty, 2017). Subjects asked about the method applied to perform the task reported both strategies linked with object rotation, creating imagery representation of a different spatial arrangement of the object, and other type of activities, e.g., counting elements of figures composed of blocks, or assessing the mutual orientation of the specific parts of the figure (Hegarty, 2010). Boone & Hegarty (2017) point out that mental rotation of an object is a dominant strategy in tasks where the angle of figure rotation does not exceed 90 degrees. With greater angles of rotation, the operation becomes more difficult as a result of which other approaches are applied. The type of strategy used seems to depend, for instance on the requirements of the task, complexity of the rotated object, its meaning and familiarity (Belhel-Fox & Shepard, 1988; Shepard & Metzler, 1988). It is worth noting that unfamiliar objects are rotated in fragments, whereas increasing experience of such objects leads to development of more integrated representations of the objects which may be rotated as a whole (Belhel-Fox & Shepard, 1988). The differences in rotation task performance by women and men may result from more general cognitive strategies used during information processing (Brandner & Devaud, 2013).
The specificity of women’s and men’s performance in mental rotation tasks is considered taking into account the differences in the use of holistic strategies versus piecemeal strategies. In accordance with the former, a figure is rotated as a whole, whereby analogue spatial processing is involved. In the case of the latter, the object is divided into parts, each of which is rotated separately and performance of the task is based on comparison of the specific features of the object without involvement of spatial thinking (Geiser et al., 2006; Strasser et al., 2010). The piecemeal strategy may cause difficulty in the case of more complex shapes, because it involves encoding, rotation and comparison of a greater number of individual properties (Heil & Jansen-Osmann, 2008; Levine et al., 2016).

In most mental rotation tasks, subjects are shown pairs of three-dimensional figures projected in two dimensions, and they are asked to decide whether the two figures are the same. While performing tasks of this type, women analyse details of three-dimensional figures and apply fragmentation strategies, for instance they count the specific blocks in the figure. On the other hand, men focus to a greater extent on the global shape, they rotate it and then compare to the target stimulus. They can more easily detect the general differences in the shapes of the objects and look for effective strategy for the specific stimulation (Hegarty, 2010). In studies where some of the target stimuli constituted a fragment of the whole figure, men switched from the holistic to piecemeal strategy, while women used the latter strategy regardless of the stimulus type (cf. Brandner & Devaud, 2013). Brandner & Devaud (2013) suggest that the differences in strategies used by women and men to solve mental rotation tasks are linked to good abilities of men to detect and transform a complex problem into a simple task requiring differentiation of patterns.

Performance in rotation tasks, based on piecemeal versus holistic strategy, is also investigated taking into account involvement of working memory. If the stimulus is analysed and rotated piece by piece (a strategy more commonly applied by women), the memory load is far greater than in a situation when the object is rotated as a whole (approach typically used by men). This may contribute to the sex-related differences observed in the speed and accuracy of performance in mental rotation tasks. Some research reports suggest that better performance in spatial tasks by men, compared to women, may be linked to larger visuospatial working memory (Coluccia & Louse, 2004).

Some studies use tasks with more choices, and subjects are asked to decide which object out of several options is the same as the target stimulus. In this case it is possible to observe some additional differences in the strategies used in performing mental rotation tasks. Men tend to rely on “match-jump strategy”, moving to the next item immediately after identifying the matching stimulus without assessing the other possible options (Hirnstein et al., 2009). Such strategy makes it possible to quickly complete the tasks, and indeed many studies find that men outperform women in this respect (Brandner & Davaud, 2013; Toth & Campbell, 2019). In contrast, women apply a more cautious strategy, they tend to more carefully assess all the options before taking a decision, hence they
need more time to complete the task (Hirnstein et al., 2009; Glück & Fabrizii, 2010; Brandner & Davaud, 2013). Toth & Campbell (2019) emphasise that, by investigating the duration of gaze fixations and number of fixation points, it may be possible to gain insight in the type of preferred strategies applied to perform tasks different than the conventional ones (i.e., based on assessment of similarities between pairs of stimuli; Shepard & Metzler, 1988). This will make it easier to determine whether a new strategy is adopted in such a case, or whether, irrespective of the type of requirements, the same methods are used to perform various tasks.

Performance in mental rotation tests may be related to the fact that men and women tend to use different frames of reference when assessing spatial stimuli. Men pay more attention to the geometry of space, whereas women tend to analyse points of orientation in space (Astur et al., 2004; com. Brandner & Davaud, 2013). Rotation tasks may be performed using a strategy dependent on or independent from the location and orientation of the object. The former requires rotation of mental representation of the object around the canonical axis. An alternative approach to the task involves the use of a strategy where mental representations encode spatial relationships between the objects. This method does not depend on the position and layout of the object, due to which mental rotation is not necessary for comparison and recognition (Just & Carpenter, 1985). Tomasino & Rumiati (2004) presented evidence showing that referential perspective and strategy applied constitute different ways of describing the same mental processes. Women possibly to a greater extent rely on the strategy where they mentally rotate the object until they reach canonical references of the remembered target object and until two angles of the figure overlap. Men performing the tasks use the horizontal and vertical axes, which makes it easier to estimate the layout of the object and the alignment of the main axis along the frame of the page or screen. Based on that, identical stimuli are detected (Collear & Nelson, 2002). Collear & Nelson (2002) showed that eliminating the page frame geometry in the conditions defined for mental rotation tasks, led to a change towards a lack of differences between men and women. In a study by Brandner & Davaud (2013) men reported they used a strategy where they referred to mentally encoded spatial relations between the objects and to geometrical clues in the space, whereas women admitted they rotated the object based on the remembered features of the target stimulus.

Mental rotation tasks may also be performed using motor strategies, where rotations are carried out based on imaginary movements of one’s own body (most commonly hand movements), whereas visual strategies are based on imaginary changes in the layout of the object in space (Wraga et al., 2003; Tomasino & Rumiati, 2004; Christie et al., 2013). Many studies use various hand positions as the stimuli, which promotes application of motor strategies by both men and women (Mochizuki et al., 2019). Mental representations of one’s own motor activity require egocentric frame of reference (Wraga et al., 2003). The study carried out by Mochizuki et al. (2019) showed that both men and women use motor
imagery to perform hand mental rotation, which is reflected by the time needed for task completion, comparable to that required for hand movement simulation mirroring object rotation. Similar conclusions were drawn from the results of a questionnaire used in that study, and related to the type of strategies applied to perform hand mental rotation tasks. Both men and women reported they used strategies based on motor and visual imagery. These results, however, are inconsistent with some performance indicators. Response time in the case of left-hand positions was longer in women than in men. It was also longer than in the case of images showing right hand positions, which suggests that women are more likely to use motor strategies. Ofte & Hugdalgh (2002) found that women need more time to transform mentally rotated components and to distinguish between left and right hand presented in a drawing. While performing rotation tasks women make greater cognitive effort than men; in the latter these processes are more automatic. Given the fact that no differences were identified in men’s response time in the case of left- and right-hand pictures, it seems that men perform the task using not only motor, but most importantly visual strategies (Mochizuki et al., 2019). Response time for left-hand images would possibly be longer (like in women) if the strategy applied was based exclusively on motor imagery. It is likely that men treat images of hands the same way as they approach objects, and they perform the task mainly using visual imagery. This opinion is supported by data from neuroimaging studies, discussed in the following section of the article (e.g., Seundrick et al., 2004; Butler et al., 2006; Heil & Jansen-Osmann, 2008).

Interesting findings are provided by studies discussing performance of mental rotation tests, where the instruction given contains a description of how to perform the task. It implies the use of a strategy independent from the observer’s point of view, where the subject should pay attention to the reciprocal orientation of the parts of a three-dimensional figure. When they are guided towards such a strategy, women can use it in a similar way as men, hence tasks of this type promote development of spatial thinking strategy to be applied to various arrangements of factors (Boone & Hegarty, 2017).

The differences between men and women seem to be related to abilities and habits in looking for and applying various methods in performing the task. Men are able, more easily and readily than women, to spontaneously detect alternative strategies for mental analysis of complex spatial material. These strategies do not always require mental transformations to be performed; some of them eliminate the need to transform the mental image in order to successfully complete the task of mental rotation (Hegarty, 2010; Bilge & Taylor, 2017; Boone & Hegarty, 2017). The structure of the task and the factors promoting a specific type of strategy, e.g., holistic or piecemeal, increase the likelihood that it will be used by the subjects performing the task. Therefore, irrespective of sex differences, it can be concluded that there is a need for a degree of flexibility in the use of specific strategies, to perform mental rotation tasks, as an ability important for effectively coping with this type of tasks in response to the requirements defined in them (Bilge & Taylor, 2017; Khooshabeh et al., 2013).
BRAIN ACTIVITY IN WOMEN AND MEN IN PERFORMANCE OF MENTAL ROTATION TASKS

Nowadays, sex differences and their effect on mental rotation task performance are investigated as part of research based on various methods of brain activity imaging, e.g., functional magnetic resonance imaging, positron emission tomography, diffusion tensor imaging, as well as event-related potential measurement.

During mental rotation, both in women and in men, the parietal, prefrontal and temporo-occipital areas are found to be active (Jordan et al., 2002; Seurinck et al., 2004; Semrud-Clikeman et al., 2012). Analysis of sex differences during performance of rotation tasks with the use of cube figure showed greater activity in the lower part of the right parietal lobe (Seurinck et al., 2004), right inferior and middle frontal gyrus region, the left praecuneus and posterior cingulate cortex, cuneus region, and the left middle occipital gyrus in men, compared to women (Semrud-Clikeman et al., 2012). On the other hand, women were found with stronger activity in the frontal lobe and fusiform gyrus, and with additional activity in left ventral premotor cortex during hand rotation (Weiss et al., 2003), which may be linked to women’s greater involvement in the use of motor imagery, compared to men, and to greater importance of visual and semantic processing in men (Seurinck et al., 2004). Jordan et al. (2002) reported greater bilateral activity in women in the intraparietal sulcus, inferior and superior parietal lobule, inferior temporal gyrus and in the premotor areas. On the other hand, men were found with significant activation in the right parieto-occipital sulcus, left intraparietal sulcus, left superior parietal lobule and primary motor cortex. Activity in the inferior temporal gyrus observed in women during mental rotation of three-dimensional figures may be associated with the fact that women tend to focus more on recognition of the object and identification of its parts, whereas men more actively respond to visuospatial characteristics. Significant relationship between the type of the rotated object and varied mental rotation task performance observed in women and men has been demonstrated in studies measuring event-related potentials (ERP) and carried out using functional magnetic resonance imaging (fMRI). It was established that letters and two-dimensional drawings do not elicit such significant differences between men and women in task performance and in patterns of brain activity as three-dimensional figures (Butler et al., 2006; Jansen-Osmann & Heil, 2007; Jäncke & Jordan, 2007; Beste et al., 2010). Interesting data suggesting different brain activity relative to sex were acquired in a study involving females and males aged 20-40 years, where assessment was carried out with the use of three-dimensional objects (Hugdahl et al., 2006). The fMRI data acquired in the whole study group showed significant increase in neuronal activity in both hemispheres, in the upper parts of the parietal lobes, although the right hemisphere was predominant. Men mainly exhibited activity in the parietal lobe and women in the right inferior frontal gyrus. Although activation
of the inferior frontal gyrus in women was basically recorded in the right hemi-
sphere, it may constitute a premise for the assumption that men and women use
different information processing strategies when solving mental rotation tasks.
Men seem to process three-dimensional objects mainly as visual objects, using
the right hemispherical mechanisms for object recognition and rotation, while
women may apply linguistic functions as mediators in solving rotation tasks, hence
the clearly visible activity of the frontal areas. Verbally defined spatial relations may
be used to check accuracy of the decisions taken with regard to the rotated objects
(Hugdahl et al., 2006). Based on the acquired findings, it was determined that the
role of the right parietal lobe may be the same in women and in men; the differences
were observed in the activation of the frontal area. Despite the similar behavioural
pattern exhibited by women and men, a different pattern of brain activation is ob-
served. Men to a greater extent use visual strategies, with predominant metric
transformation associated with parietal cortex activation, whereas women tend to
prefer serial, categorical strategies in which language functions, connected with
the left frontal areas, play a mediatory role. Verbal and piecemeal strategies fa-
voured by women in mental rotation tasks also correspond to significant activation
in the inferior temporal gyrus (Hugdahl et al., 2006).

A study performed using fMRI technique showed greater activation of the as-
soiation cortex as well as lower and medial areas of prefrontal cortex in women,
compared to men, during rotation of three-dimensional figures (Butler et al.,
2006). These areas are involved in “top-down” processing where it is necessary
to maintain calculations and visuospatial transformations in working memory.
The identified pattern of activity suggests that, while performing mental rotation
tasks, women mainly apply “top-down” processes requiring greater cognitive ef-
fort (Hugdahl et al., 2006; Heil & Jansen-Osmann, 2008; Semrud-Clikeman et al.,
2012). Greater cognitive engagement exhibited by women during performance of
tasks is also shown by findings of studies based on eye tracking, which reported
larger pupil diameters in women than men during performance of mental rotation
task (Toth & Campbell, 2019). On the other hand, men mainly exhibit activity in
the primary sensory cortex and basal ganglia, involved in implicit learning. Altered
activation was also observed in men, in the praecuneus which is believed to be
involved with mental imagery. This may be associated with the fact that men
more commonly refer to strategies based on visual imagery, even in rotation of
hand images (Mochizuki et al., 2019). Activity in these areas corresponds to the
more automatic “bottom-up” processes (Butler et al., 2006; Semrud-Clikeman et
al., 2012). Functional assessments in conjunction with performance indicators
show automatic evocation of visual-vestibular neural networks by men during
mental rotation tasks, which may represent effective, unconscious, neuronal
strategy associated with better visuospatial abilities observed in men, compared
to women (Butler et al., 2006; Levine et al., 2016). The pattern of right hemisphere
activity in men possibly reflects the use of holistic rotation strategies, whereas the
more analytic, piecemeal strategies may presumably be linked to the bi-hemi-
spheric pattern of brain activity in women (Corballis, 1997; Heil & Jansen-Os-
mann, 2008; Xu & Franconeri, 2015), although in the light of the current evidence, approaching the strategy used in terms of a dichotomy does not provide adequate explanation of sex differences in mental rotation performance (Levine et al., 2016).

The use of more automatic “bottom-up” processes and predominant engagement of the right hemisphere in men, as well as the use of the left hemisphere and the “top-down” processes by women were also reported by Sharma et al. (2018). The evoked potentials method was applied to assess neuronal activity during the specific stages of mental rotation tasks involving comparison of two arrangements of objects. Sex differences were observed at the early stages of rotation task performance, i.e., during identification of the stimulus (Ruggeri et al., 2020) and later during the process of mental rotation (Schendan & Lucia, 2009). The importance of more basic aspects of mental rotation was explored by the event-related potentials study carried out by Ruggeri et al. (2020). Processes such as visual perception or attention might significantly impact the later processes and contribute to the differences in accuracy of task performance (Ruggeri et al., 2020). The ERP studies exploring sex differences in the early processing stage of mental rotation tasks revealed mixed results (Beste et al., 2010; Jaušovec, 2012). Interindividual differences in mental rotation to some extent may depend on transient brain states observable at the early stages of visual processing. Research findings show that men take more time processing visuo-spatial information, whereas women, even at the early stages of task performance, initiate processing of information of different nature than visuo-spatial data (Ruggeri et al., 2020). Sharma et al. (2018), making reference to higher order cognitive processes, suggest that men to a greater extent than women engage visual operating memory during performance of mental rotation tasks. Wei et al. (2016) revealed that the grey matter volume of a male’s right anterior hippocampus, which encodes new visuospatial information, is larger than that of a female. The role of the anterior hippocampus is especially important in the case of new or abstract 3D figures.

It should be emphasised here that the related research reports include studies which show that the strategies applied during performance of mental tasks are not always consciously used by the subjects. Some of these strategies may reflect the implicit mental process. Induced unknowingly, they produce an effect where e.g., representation of one’s own hand is superimposed on the image shown in the task (de Lange et al., 2006; Ionta & Blanke, 2009). Because of this, it may be difficult to arrive at indisputable and clear conclusions related to this subject matter, based exclusively on behavioural differences and responses to questionnaires. Implicit motor imagery induced by hand pictures may be associated with mirror neuron system. Recognised among locations of mirror neurons, the areas of premotor cortex and intraparietal sulcus are activated during observation of hand movements and during performance of hand mental rotation tasks (Mochizuki et al., 2019). In women activation of these regions during observation of hand movements is stronger than in the case of movement of other stimuli (Cheng et al., 2008).
In view of the above, the sex differences may be linked to different regulation of balancing between motor and visual imagery during performance of complex cognitive tasks. Additionally, more general cognitive, neurophysiological and morphological differences between men and women may play a significant role in generating these differences (Mochizuki et al., 2019). It seems that differences in brain activity exhibited by women and men during performance of mental rotation tasks are not in a fixed and invariable way attributable to the neuronal organisation. Rather, they should be treated as a result of sex-specific preferences in choosing the strategy and way of responding to a specific type of cognitive tasks (Jordan et al., 2002). It should also be considered, as pointed out by contemporary neuroscientists, that this outcome may be influenced by the system of one's own self (biological, emotional and cognitive) and even social and cultural, which is related in part to gender (Gazzaniga 2013; Pąchalska 2019).

CONCLUSIONS
1. The choice of specific strategies for performing mental rotation tasks is associated with the characteristics of cognitive functioning exhibited by women and men and the methods used by them in visuospatial information processing.
2. The use of a specific strategy in mental rotation tasks is determined not only by sex differences, but also by the characteristics of the task parameters, e.g., type of stimulus, instruction, limited response time, and rotation angle.
3. Effectiveness in mental rotation tasks is significantly related to the ability to flexibly adjust the strategy to the conditions defined for the task performance, e.g., by shifting between various methods of assessing the object requiring rotation.
4. Neuroimaging studies investigating mental rotation processes show that the strategies used to perform mental rotation can be adopted for different types of stimuli. Perhaps, for the subjects this is a way of coping with a difficult task. By undertaking specific strategies, it may be possible for compensate for certain less developed abilities in assessing spatial transformations.

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