The Effect of Texture on Face Identification and Configural Information Processing

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Shape and texture are an integral part of face identity. In the present study, the importance of face texture for face identification and detection of configural manipulation (i.e., spatial relation among facial features) was examined by comparing grayscale face photographs (i.e., real faces) and line drawings of the same faces. Whereas real faces provide information about texture and shape of faces, line drawings are lacking texture cues. A change-detection task and a forced-choice identification task were used with both stimuli categories. Within the change detection task, participants had to decide whether the size of the eyes of two sequentially presented faces had changed or not. After having made this decision, three faces were shown to the subjects and they had to identify the previously shown face among them. Furthermore, context (full vs. cropped faces) and orientation (upright vs. inverted) were manipulated. The results obtained in the change detection task suggest that configural information was used in processing real faces, while part-based and featural information was used in processing line-drawings. Additionally, real faces were identified more accurately than line drawings, and identification was less context but more orientation sensitive than identification of line drawings. Taken together, the results of the present study provide new evidence stressing the importance of face texture for identity encoding and configural face processing.

Key words: face perception, face identification, texture, shape

The human face is a complex composition of various features whose distinctiveness makes every face unique and individual, which allows recognizing familiar people within milliseconds. Processing faces is one of the most important, but also one of the most complex tasks one has to perform in daily life. We do not only recognize people we already know, but we are also able to remember a face after seeing it for a very short period of time (Chance, Goldstein, & McBride, 1975). According to Ellis (1986), we can name about 700 known faces and we are able to recognize faces even if they are shown to us with a significant delay and if presented to us only once (Chance, Goldstein, & McBride, 1975). Given the aforementioned characteristics of faces, one question naturally arises from a psychological point of view, namely how does recognition and processing of faces actually work and which factors have a main influence on those processes?

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In literature, there is a distinction made between three kinds of information that can be used in face recognition: isolated features, first-order relations and second-order or configural relations (Diamond & Carey, 1986). Isolated features can be specified without reference to other parts of the stimulus (e.g., hair, eyebrows, eyes). First-order relations refer to the relations among these basics facial features which are shared by all faces and allow distinction between faces and non-facial objects (e.g., nose is located above a mouth and eyes are located above a nose). Second-order relations refer to the set of spatial relations that characterizes the specific arrangement of the basic features of an individual face. The information given by second-order (configural) relations helps to recognize faces because of the relative distances between facial features (e.g., eyes and nose) (Nishimura & Maurer, 2008). The exact nature and processing mechanisms underlying face perception are, however, not fully understood. While some experimental evidence suggest parallel processing of featural and configural information, but with more weight on the later (Bartlett & Searcy, 1993; Diamond & Carey, 1986; Rhodes, 1988; Rhodes, Brake, & Atkinson, 1993; Searcy & Bartlett, 1996), the proponents of holistic hypothesis propose that faces are perceived and remembered as unparsed perceptual wholes (i.e. a facial Gestalt) whose parts belong together (Maurer, Le Grand, & Mondloch, 2002; Tanaka & Farah, 1993; Young, Hellawell & Hay, 1987). Although there is no consensus about terminology, and distinction between configural and holistic processing remains difficult, there are few experimental paradigms apt to measure these aspects of face processing.

Evidence of holistic face perception comes from three basic findings. One is the composite effect, which shows that it takes longer to identify a person who appears as the upper and lower part of a composite face when the two parts are aligned, compared to when the halves are misaligned (e.g., Young et al., 1987). The second finding known as “the part-to-whole effect” refers to the better identification of a facial feature (e.g. a nose) when it is seen in the context of a face that has previously been viewed, compared to seeing the part in isolation (e.g., Tanaka & Farah, 1993). The third finding is the context effect that refers to the holistic integration across the whole face between internal (eyes, eyebrows, nose, mouth) and external facial features (hair, head– and face outline). The contribution of external features to face identification (Megreya & Bindemann, 2009; Nachson, Moscovitch & Umilta, 1995; Veres-Injac & Persike, 2009) and holistic face processing (Andrews & Thompson, 2010; Frowd et al., 2012; Meinhardt-Injac, Meinhardt, & Schwaninger, 2009; Nachson et al., 1995; Sinha & Poggio, 1996; Veres-Injac & Schwaninger, 2009) is well demonstrated. External features also strongly influence the processing of internal facial features suggesting that faces are seen as holistic percepts. This claim is corroborated by neuroimaging data providing evidence that external facial features are an integral part of holistic face representations in the fusiform face area (Andrews, Davies-Thompson, Kingstone & Young, 2010; Axelrod & Yovel, 2010, 2011). Importantly, all three findings (i.e., composite effect, part-to-whole effect and context effect) have been reported only for faces, but not for common objects.
suggesting that holistic processing mechanisms are face-specific. The holistic processing is particularly strong when faces are seen upright, in their canonical orientation, but it is strongly hampered in inverted orientation. However, the inversion effect (Yin, 1969) is not just related to the aspects of holistic face processing – i.e., automatic integration of facial parts in a holistic percept – but also to the processing of configural relations in faces (e.g., Meinhardt-Injac, Persike, Meinhardt, 2011; Maurer et al., 2002; Thompson, 1980) and objects of expertise (Diamond & Carey, 1986; Bilalic, Langner, Ulrich, & Grodd, 2011).

The main question addressed in the present study is in how far holistic face processing is supported by shape and texture (also referring to terms like surface-reflectance or pigmentation). For accurate face identification, neither texture nor shape alone are sufficient (Jiang, Blanz & O’Toole, 2006; O’Toole, Vetter, & Blanz, 1999; Russell, Sinha, Nederhouser, & Biederman, 2004, Russell, Biederman, Nederhouser, & Sinha 2007). However, since shape alone provides information about isolated features (e.g., size of eyes), as well as configural relations between them (e.g., inter eye distances), it is widely accepted that face-shape per se might trigger holistic processing. Less clear, however, is in how far holistic face processing is supported by texture (Hole, George & Dunsmore, 1999; Jiang, Dricot, Blanz, Goebel & Rossion, 2009; Leder 1996, 1999; Meinhardt-Injac, Persike & Meinhardt, 2013; Russell et al., 2007).

In order to assess the influence that face texture and shape have on recognition, Leder (1996; 1999) used line drawings portraying a face without its texture. Line drawings represent faces and keep the position, size, and borders of its features, but lack texture cues. As Bruce already stated in 1988, photographs can be seen as a realistic portray, wherefore comparing line drawings to photographs investigates the contribution of texture on face processing (Bruce, 1988). Previous investigations (Davies, Ellis, & Shephert, 1978; Bruce, Hanna, Dench, Healey & Burton, 1992) have found that line drawings are always identified worse than photographs, regardless of the viewpoint and the familiarity of the presented person to the participants. Leder (1996; 1999) investigated the detection sensitivity and its dependence on texture by showing line drawings instead of photographs and varying the size of the targets’ eyes. As a result, participants’ sensitivity to recognize configural changes decreased with linedrawings compared to photographs. Based on the data, he concluded that the lack of texture does not cause an absolute, but a relative decrease of performance and an attenuated weighting of configural information.

In a recent study, the contribution of texture information to holistic face processing was studied by Meinhardt-Injac et al. (2013) by comparing full-color photographs to line drawings. Investigating summation, context and orientation effects, they found that real face, but not line drawing stimuli were always processed holistically even when the task required only detection of local changes. With shape information (line-drawings) alone, participants performed very well in a change detection task and their performance was not affected by inversion. The authors concluded that participants were using local cues rather
than holistic representation. Performance for real face stimuli was even better than for line drawings, but only when the stimuli were presented in upright orientation and when all internal features were manipulated in size (summation effect). For inverted orientation, performance in change detection task did not differ between real faces and line drawings. Assuming that orientation is a determinant of holistic face processing, the authors concluded that real faces were processed holistically.

However, the faces were not equalized in color, which might have caused stronger holistic effects for real faces and higher identification rate. Russell et al. (2007) have found an asymmetry in the use of shape and texture cues depending on the presence of color. In gray-scale pictures, shape cues were more efficiently used than reflectance cues, whereas subjects performed better using texture than shape information with color versions of the same images. Colored faces were also better recognized than gray-scale images and were less affected by inversion (Russel et al., 2007; Yip & Sinha, 2002). Lee and Perret (2000) showed the importance of texture and shape by finding an advantage for line-drawn and photographic shape caricatures of faces compared to veridical faces in terms of recognition. In order to re-evaluate the importance of texture cues for holistic face processing, an adapted version of the paradigm by Meinhardt-Injac et al. (2013) was employed, with some distinctions. First, gray-scaled instead of colored faces were used and compared with the line drawings of the same faces. Second, the strength of holistic and configural information processing in both stimuli categories was measured as the magnitude of the context and inversion effects.

Method

Participants

18 students of the Psychological Department of the Johannes Gutenberg University Mainz participated in this experiment and were rewarded with course credits. The average age of the test group was 22.6 years (range 20–25). Nine of the 18 participants were females. All participants had normal or corrected to normal vision.

Stimuli and Apparatus

Frontal view photographs of five male face models were used as templates for stimulus construction. The photographs were taken in front of a white background and under the same lightning conditions. They were converted to 300 × 400 pixel grayscale images and equalized in contrast. Line drawings were created by manually tracing photographs using Ulead PhotoImpact 10 and only showed the shape of the face, the hair, and all internal features (i.e., eyes, eyebrows, nose, mouth), without providing any information of texture or shadows (see Meinhardt-Injac et al., 2013, for more details about stimuli construction). None of the faces were presented with a beard, glasses, or jewelry.

The original grayscale photographs and line drawings were systematically edited by changing the size of the eyes and eyebrows compared to the size of the whole face in equally spaced steps of 3.5% in a range from 82.5%–114% of the original size (i.e., 100%). This resulted in ten different versions of the same-identity face stimuli concerning eye and
eyebrows size: 82.5%, 86%, 89.5%, 93%, 96.5%, 100%, 103.5%, 107%, 110.5%, and 114%.

In the next step, the internal features of each version of the targets were cut out to create cropped stimuli without context (i.e., without face- and head-outline). An overview of the independent variables are given below, an example of the different presentation forms of one face is given in Figure 1.

**Stimulus.** Fifty percent of the time, the stimulus was a black-and-white photography (providing information of texture and shape) and 50% a line drawing (only providing shape information).

**Orientation.** Stimuli were presented in upright and in inverted orientation for half of the trials. In inverted orientation, the stimuli were flipped 180 degrees.

**Context.** Two different presentation modes were given: 1) cropped faces including only the internal features (eyes, eyebrows, nose and mouth) and 2) the whole faces showing a naturally looking face with hair and head- and face-outline.

The experiment was executed with *Milliseconds Inquisit 2.0* runtime units. Stimuli were displayed on NEC Spectra View 2090 TFT displays in 1280 x 1024 resolution at a refresh rate of 60 Hz. The viewing distance from participant to display equaled approximately 70 centimeters. Stimulus patterns and masks subtended 300 x 400 pixels, which corresponds to 12 x 15 cm of the screen, or 9.65° x 12° measured in degree of visual angle at 70 cm viewing distance. Subjects used a distance marker but no chin rest.

**Figure 1.** Example of stimuli for five of the ten different sizes. Rows a) and c) show targets whose eyes have been scaled for full faces, and in b) and d) for cropped faces.
Experimental Design and Procedure

Percent correct data were measured as dependent variable in a 3-factor repeated measurements experimental design with stimulus (2; real faces vs. line drawings), orientation (2; upright vs. inverted), and context (2; full face vs. cropped face) as independent variables. For each experimental condition, 16 repetitions for same and 16 repetitions for different trials were conducted, resulting in 256 trials per participant.

In each trial, the subjects had to perform a change-detection task and a forced-choice identification tasks, an example for one trial is given in Figure 2. In the change-detection task, participants were asked to judge whether the size of eyes and eyebrows in two sequentially presented examples of a face was changed or not. Different trials were realized by randomly pairing two instances from the pool of 10 differently scaled versions of the same face. The two presented faces differed by 17.5% of the original size, since this difference is detected most accurately (see also Meinhardt-Injac et al., 2013). Note that different trials always resulted from the difference between the scaling of the two presented faces, thereby avoiding absolute cues. An example is given in Figure 3. The presentation positions of each of the two face images were shifted by 20 pixels away from the center in random directions in order to preclude pixel matching. If faces differed, subjects were instructed to answer yes (i.e., there is a change), and no otherwise. The responses were given by pressing corresponding buttons on the keyboard. The assignment of answers (yes/no) to the buttons was counterbalanced across participants. In half of the trials, the faces differed in size of their eyes and eyebrows, but were always versions from the same original, i.e., were identical with respect to all other characteristics (e.g., hair, nose, mouth — see Figure 1).

The second task required identification of the just-presented face in a forced-choice identification task. After the participants had responded to the change detection task, a blank screen was shown for 200 ms and afterwards they were asked to identify the just-presented face (target face) among two distractor faces. All three faces (target and two distractor faces) were presented simultaneously until the response, and were always original faces (100 % of the original size). Answers were given by pressing corresponding buttons on the keyboard in order to identify the target: “y” for the left face, “c” for the right face, and “x” for the face in the middle. As the target always figured among the three presented faces, this was a forced-choice task, which means that the participants always had to make a decision and were not able to answer “none of them”. The position of the target was randomized across the trials and participants. The faces were presented in upright and inverted orientation, depending on the orientation of the stimulus in the change-detection task (see Figure 2).

The experiment consisted of four blocks: real faces presented upright, real faces presented inverted, line drawings presented upright, and line drawings presented inverted. The presentation of experimental blocks was randomized over participants, whereas context (cropped vs. full faces) was randomized within each block. The temporal order of events in a trial sequence was as follows: fixation (300 ms); first stimulus frame (350 ms); mask (350 ms); blank (200 ms); second stimulus frame (350 ms); mask (350 ms); change detection task (until response); blank (200 ms); identification task (until response). An example for one trial is depicted in Figure 2.

![Figure 2. Example for one trial of the block with the stimulus condition line drawings and orientation upright.](image-url)
Figure 3. Some possible combination of the stimuli. Trials with and without change in the size of eyes and eyebrows are realized by pairing different faces. Figure 1. Example of stimuli for five of the ten different sizes. Rows a) and b) show targets whose eyes and eyebrows have been scaled for full faces, and c) and d) for cropped faces.

Results

The Change Detection Task

A 3-factor repeated measurements ANOVA (see Figure 4) was calculated with stimulus (2; real faces vs. line drawings), context (2; full face vs. cropped face), and orientation (2; upright vs. inverted) as within-subjects factors. The main effect of context (cropped face vs. full face) was statistically significant: $F(1, 17) = 8.002, p < .01$, partial $\eta^2 = .32$. The change detection was more accurate with full faces than with cropped faces without external contour. Furthermore, there were no significant main effects of stimulus and orientation, but a significant two-way interaction between stimulus x orientation: $F(1, 17) = 9.38, p < .005$, partial $\eta^2 = .35$, and a significant three-way interaction between stimulus x orientation x context: $F(1, 17) = 8.86, p < .005$, partial $\eta^2 = .34$. No other interactions were significant. The data are shown in Figure 4.
Figure 4. Mean proportion correct in the change detection task for real faces and line drawings. The left box indicates the results for real faces (black circles) and line drawings (gray squares) in upright orientation, while the right box indicates inverted orientation of the stimuli. The x-axis shows two levels of context, where full or cropped stimuli were presented.

Figure 5. Orientation and context effects calculated as differences of proportion correct data (see x-axis) for real faces (open symbols) and line drawings (filled gray symbols). The box-whiskers indicate mean with standard error (box) and confidence interval (whiskers). An effect is significant if 0 is outside the confidence interval (CI).

In order to further analyze the three-way interaction \([\text{stimulus } \times \text{ orientation } \times \text{ context}: F(1, 17) = 8.86, p < .005, \text{ partial } \eta^2 = .34.]\) and to evaluate
inversion and context effects for real faces and line drawings, the differences of the data were calculated on the level of individual measurements. The orientation effect was calculated as accuracy difference between upright and inverted presented stimuli (\(\Delta P = P_{UPR} - P_{INV}\)), for both stimulus and context levels. The context effect was calculated as the accuracy difference between full and cropped faces (\(\Delta P = P_{FULL} - P_{CROPPED}\)), again for both stimulus types and orientations. The results are shown in Fig. 5. Note that since Figure 5 shows difference measures, the effect is significant if 0 is outside the confidence interval. For real faces, the accuracy difference between upright and inverted presented stimuli was positive, which is due to higher accuracy in the change detection task in upright orientation. Additionally, accuracy in change detection with real faces was higher for full than cropped faces, but only in upright orientation. For line drawings, however, the changes in size of eyes and eyebrows were more accurately detected in inverted than in upright presented stimuli. Moreover, the context seems to be particularly supporting in inverted orientation and has virtually no effect on the change detection in upright orientation. This is exactly the opposite pattern of the data when compared with real faces (see Figure 5).

Identification task

A 3-factor repeated measurements ANOVA was calculated with stimulus (2; real faces vs. line drawings), context (2; full face vs. cropped face) and orientation (2; upright vs. inverted) as within-subjects factors. The main effects of stimulus \([F(1, 17) = 24.92, p < .001, \text{ partial } \eta^2 = .59.]\), context \([F(1, 17) = 57.17, p < .001, \text{ partial } \eta^2 = .77]\) and orientation \([F(1, 17) = 6.46, p < .05, \text{ partial } \eta^2 = .27.]\) were all statistically significant. The interaction between stimulus x context was also statistically significant \([F(1, 17) = 20.85, p < .001, \text{ partial } \eta^2 = .55.]\). No other two- or three-way interactions reached statistical significance. Again, the orientation and context effects were calculated as the accuracy difference at the level of individual measurements. The results are shown in Figure 7.

In sum, identification of the two facial stimulus categories was very successful (see Figure 6). However, there were also marked differences between the accuracy of data obtained with real faces and with line drawings (main effect of stimulus). With real faces, accuracy reached ceiling level with about 97% of correct responses. Identification of line drawings was less accurate and depended strongly on the presence of face context (i.e., external features). External facial features were used as a cue for identification of real faces, but they were especially important for identification of inverted presented real faces (see Figure 7). Orientation effects were overall small and only significant for cropped real faces (see Figure 7).
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Figure 6. Mean proportion correct in the identification task for real faces (black circles) and line drawings (gray squares). The x-axis shows context level (full vs. cropped), on the left side are the data for upright and on the right side for inverted presented stimuli.

Figure 7. Orientation and context effects in identification task. The effects are calculated as differences of proportion correct data (see x-axis) for real faces (open symbols) and line drawings (filled gray symbols). The box–whiskers indicate mean with standard error (box) and confidence interval (whiskers). An effect is significant if 0 is outside the confidence interval (CI).
Discussion

To what extent do texture cues trigger holistic face processing? In order to shed light on the question raised above, this study compared participants’ performance for real faces, presented as gray-scaled photographs, with the performance for line drawings, which serve as a representation of a face without its texture. The strength of context and inversion effects was used as the measure of holistic and configural face processing. In the experiment, the participants had to perform two different tasks: detect a change of size in the target’s eye region (i.e., eyes and eyebrows) and identify the previously shown target among distractor faces. It was crucial for the experiment’s success and viability to include both tasks in order to ensure that participants do not only focus on the eyes as a separate feature, but on the face as a whole. Note that by changing the size of eyes and eyebrows, not only configural aspects of a face (i.e., spatial relations among eyes region and other internal features) are altered, but also the featural aspects (i.e., the absolute size of eyes and eyebrows) (see also Riesenhuber & Wolff, 2009). The context effect was varied by presenting either full faces (with external features) or just cropped internal features without face contour, while faces were presented in upright and inverted orientation. Based on the data obtained in the present study, we come to the conclusion that texture cues trigger configural face processing and improve participants’ performance in face identification. The presence of external features is a supporting, but not a necessary condition for processing configural information in real faces. However, external features are an important cue for face identification, especially when line drawings are used as stimuli. The results are discussed in more detail below.

In the detection task, maximal performance was reached for real faces in full face context and upright orientation. Comparable performance for line drawings was reached in full face context, but in inverted orientation. Similarly, face context in form of external features was helpful for change detection in upright presented real faces and also for inverted presented line drawings. Taken together, these findings indicate that configural (orientation effect) and holistic (context effect) information is encoded when change detection in real faces is required. Facial context supports processing of configural information, but is not necessary to trigger configural processes in real faces as an inversion effect was also obtained for cropped faces (see Figure 5). The opposite pattern of the data with line drawings suggests that the absolute size of eyes and eyebrows was used to complete the task rather than altered configural relations between facial features.

With respect to the face detection task, the results obtained in the present study are in line with previous findings, suggesting the importance of face texture for encoding of configural information in a face (Meinhardt-Injac et al., 2013; Leder, 1996; Russel, et al., 2007). Namely, in a complex experimental design, Meinhardt-Injac et al. (2013) have found evidence that face shape and texture may support different aspects of face processing. Whereas shape is important for initial stages of face perception and feature binding, texture seems to be involved in processing configural or second-order relations. Similar findings indicating that
texture has an important impact on configural and face-specific processing were reported in two studies by Leder (1996, 1999). In all three studies, the comparison between line drawings and real faces provided stable effects. Nevertheless, in this kind of stimuli, shape and texture are not independently manipulated, but conclusions are driven in a subtractive way as the difference between real faces (= texture + shape) and line drawings (= only shape). Since it might be taken as a limitation of the study, it is important to note that similar findings were found also when face shape and face texture were manipulated independently (Russel et al., 2007). By asking the participants to do a forced-choice matching task, the authors found that inversion disrupted performance about equally for faces differing only in texture or only in shape (Russel et al., 2007). They concluded that poorer recognition of inverted faces is not specific to face shape, but also caused by impairments in processing texture cues.

Within the identification task, real faces (grayscale and equated in image similarity) were recognized more accurately than line drawings, thereby supporting previous claims that texture is an intrinsic property of face identity (Bruce et al., 1992; O’Toole, et al., 1999; Russell, Sinha, Biederman, & Nederhouser, 2006; Russel et al., 2007; Vuong, Peissig, Harrison, & Tarr, 2005). By using faces with only texture information or only shape-from-shading information, Troje and Bülthoff (1996) have demonstrated that texture facilitates face learning and generalization from learned views to new views. As adding shape-from-shading to the line drawings dramatically improves recognition of familiar faces (Davies et al., 1978; Bruce, Hanna, Dench, Healey, & Burton, 1992), the study by Troje and Bülthoff (1996) provided strong evidence supporting importance of texture for face perception and recognition. The particular importance of texture is unique for face recognition since no similar effect has been found in object recognition tasks (Nederhouser, Yue, Mangini, & Biederman, 2007).

More accurate identification of real faces (gray-scaled or colored) compared to line drawings has been reported previously (Leder, 1996, 1999; Meinhardt-Injac et al., 2013). Relative importance of color in face identification tasks was typically demonstrated with familiar faces (Lee & Perret, 2000; Yip & Sinha 2002). It seems to be of less relevance when unfamiliar faces are used as results of this study and the study of Meinhardt-Injac et al. (2013) are similar, even though this study used gray-scaled instead of colored faces. Hence, face identification in these two studies was probably not influenced by color cues, but by texture itself. Alternatively, overall high identification rates and small number of faces used might occlude importance of the color for identification of unfamiliar faces. Successful identification of line drawings supports this notion. Although less accurate compared to real faces, the identification of line drawings was quite accurate. However, identification of line drawings was more strongly affected by face context than the identification of real faces. Face context or external facial features are particularly important for identification of unfamiliar faces (e.g., Frowd, Bruce, McIntyre, Hancock, 2007; Veres-Injac & Persike, 2009) and are also less sensitive to orientation than internal features.
alone (Meinhardt-Injac et al., 2009; Nachson & Shechory, 2002). The strong context effects in combination with lacking inversion effects and a significant drop in the accuracy data when cropped stimuli are used, indicate that subjects have used rather part-based than holistic strategies when identifying line drawings (Leder, 1996, 1999). In real faces, a context effect was present, but to a lesser extent than in line drawings. Additionally, there was a significant effect of inversion for cropped presented faces. Together, these two findings suggest that 1) external features were less important for identification of real faces than line drawings and 2) configural information was processed only in real faces, but not in line drawings. The encoding of configural information in real faces most likely accounts for high accuracy levels with cropped faces in upright orientation (see Figure. 6).

Conclusions

Taking into consideration the influence of texture on face processing and recognition, this study finds that texture has a significant impact on holistic face processing. Findings are in line with previous studies, suggesting that both, shape and texture cues, are encoded when processing faces (Meinhardt-Injac et al., 2013; Jiang et al., 2006; Leder, 1996; Russel et al., 2007).

References


