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Review

A closer look at the paralyzed face; a narrative review of the neurobiological basis for functional and aesthetic appreciation between patients with a left and a right peripheral facial palsy

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ABSTRACT Background: The facial nerve or *n. facialis* (NVII) is the seventh cranial nerve and it is responsible for the innervation of the mimic muscles, the gustatory organ, and the

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neurobiology, cosmetic appreciation;
socials aesthetics;
hemispheric specialisation

secretomotor function to the salivary, lacrimal, nasal and palatine glands. Clinical presentation of Facial Palsy (FP) is characterized by unilateral facial asymmetry and may present with a change in taste, decreased saliva production, and dysarthria. A facial palsy has a notable effect on the facial appreciation by both the patient and the environment and also affects quality of life and emotional processing. There appear to be differences in the appreciation of people with a left and right facial palsy.
Purpose of this review: The purpose of the review is to give an overview of the anatomy of the facial nerve, neuro-anatomy of face processing, and hemispheric specialization and lateralization. Further,an overview is given of the clinical studies that translated the neuro-anatomical and neurobiological basis of these concepts into clinical studies.
What this review adds: This review emphasizes the neurobiological evidence of differences in face processing between the left and right cerebral hemisphere, wherein it seems that the right hemisphere is superior in emotional processing. Several theories are proposed; 1) a familiarity hypothesis and 2) a left-right hemispheric specialization hypothesis. In clinical studies, promising evidence might indicate that, in patients with FP, there is indeed a difference in how left and right FP are perceived. This might give differences in decreased quality of life and finally in occurrence of depression. Further research must aim to substantiate these findings and determine the need for altering the standard therapeutic advice given to patients.

Contents

Introduction

The facial nerve or *n. facialis* (NVII) is the seventh cranial nerve and it is responsible for the innervation of the mimic muscles, the gustatory organ, and the secretomotor function of the salivary, lacrimal, nasal, and palatine glands.[1,2] A facial palsy (FP) is a paralysis of the facial nerve which can be localized in the central nervous system (central facial palsy, CFP) or in the trajectory of the facial nerve (peripheral facial palsy, PFP). Annual incidence of PFP's varies between 30 and 40 per hundred thousand.[1-3] Even though the causes for a facial palsy are abundant (*e.g.* viral, inflammatory, traumatic, iatrogenic, neoplasms), the exact etiology is found in only about one-third of the patients.[1]

Clinical presentation of FP is characterized by unilateral facial asymmetry, insufficient eyelid function or eye protection, a change in taste, decreased saliva production, and/or dysarthria. Uncommon symptoms include involvement of other cranial nerves, headache, and onset of symptoms after a tick bite or head injury, hearing loss, and/or dizziness. (1, 2) The severity of the palsy is clinically assessed most commonly by the House-Brackmann scale[4], ranging from I (normal function) to VI (complete paralysis), although other scales exist. Approximately 75% of the patients with idiopathic peripheral facial palsy (IPFP) recover spontaneously within six months without any permanent damage.[1,5] The remainder may endure ongoing sequelae such as weakness (or paralysis). In cases of any degree of recovery, involuntary movements of the mimic muscles like eye narrowing, oral commissure elevation, platysma spasms, *etc.* may occur which are called synkineses. In an extreme degree, these can result in a spasmodic frozen face, which in fact is comparable with a paralysis.

Besides the functional problems, patients with FP may also experience psychosocial consequences.[6-10] Both can have an impact on the overall Quality of Life (QoL).[11]

The facial palsy has an impact on the facial appreciation of the patient, by himself and by the environment. In the literature, there is a clear definition of facial perception, *e.g.* 'any higher level of visual processing of faces, including extraction from a face of any information regarding an individual's identity'.[12] The complex concept of facial perception combines the visual sensory input with retrievable memory.[12,13] This is an important inherited ability; neonatal studies indicated that infants would track a moving face much earlier than other moving patterns of comparable contrast and complexity. This occurs just after 30 minutes of age.[14] The ability of facial perception is important to distinguish different people in a social and professional situation.[15,16] In daily life, we encounter new and familiar faces, which also embody (new) emotions and unspoken communications.[17] All these features are commonly signalled through facial expressions.[18,19]

It is expected and studied that the earlier mentioned social interactions are impaired in patients with FP. Many studies have shown that psychological stress was prevalent in patients with FP, for which either the social impairment and/or the thought of social impairment might be the cause. Van Swearingen et al.[20,21] found that psychological stress was the single predictor of social disability for PFP. Both Sugiura *et al*.[22] and Stuart et al.[23] found that high levels of psychological distress were present among patients with PFP, often three to five times higher than compared with the normal population. Goines et al. assessed the social impact of FP and observed a decreased attractiveness, a decreased perceived QoL, and a decreased willingness to converse with patients with FP, scored by 84 casual observers.[24] Of special interest is the more frequently reported phenomenon that left PFP is differently assessed than right PFP in terms of social interaction[6,7], cosmetic appreciation[9,10,25], and risk for anxiety and depressive disorders.[8]

The purpose of the review is to give an overview of the anatomy of the facial nerve, the neuro-anatomy of face processing, and hemispheric specialization and lateralization. Further, an overview is given of the clinical studies that translated the neuro-anatomical and neurobiological basis of these concepts into clinical studies.

Anatomy of the facial nerve

The facial nerve is one of the twelve cranial nerves, is part of our peripheral nervous system, and arises from the brain and brainstem. It contains visceral-afferent, visceral-efferent, and somato-afferent branches.[26,27] The facial nerve originates from nuclei located in the pons and nuclei located in the medulla oblongata.[27] The course of the facial nerve from the brainstem to end organ is divided in six segments; intracranial, internal meatal, labyrinthine, tympanic, mastoid, and extratemporal.[26-30] Distal to the genicular ganglion, between the internal meatal and labyrinthine organ, collateral branches from the facial nerve arise, beginning with the stapedial nerve and ending with the chorda tympani.[30] The facial nerve exits the cranial base through the stylomastoid foramen and the posterior auricular nerve, which innervates the occipitofrontal muscle and branches off[26].

After passing through the stylomastoid foramen, the facial nerve bifurcates and finally terminates into the following branches: the temporal, zygomatic, buccal, mandibular, and cervical branch.[26,27] The most important muscles of facial expression, which are innervated by the facial nerve, are the frontalis, orbicularis oculi, orbicularis oris, zygomaticus, levator labii superioris, depressor anguli oris, buccinators, corrugator, and platysma.[26,27]

Due to its anatomical location and pathway, the facial nerve is left vulnerable to different types of damage.[28-30] The close relation of the facial nerve to the internal facial canal of the inner ear leaves the facial nerve vulnerable to damage caused by traumatic lesions of the os petrosum, mastoiditis, middle ear infections, or iatrogenic damage caused by surgical interventions of the middle and inner ear.[28-30]

Another advantage of knowing the anatomy of the facial nerve is the ability to locate the site of the lesion. Notably, it allows clinicians to determine if the lesion is peripheral or central. Research shows that the nuclei[26,27] of the temporal and zygomatic branches are being innervated by both hemispheres, whereas the nuclei of the buccal and mandibular branch receive information solely from the contralateral hemisphere.[26,27] Thus, a lesion in a cerebral hemisphere leaves the upper third of the face intact, whereas a lesion distal from the facial nucleus affects the whole facial musculature.[1,26,27]

Neuro-anatomy of face processing

Face processing and perception have been the center of extensive neurobehavioral research for a long time. Functional MRI (fMRI) studies have identified cortical regions that generate a highly selective neural response for faces.[12,31] Each specific region has been studied extensively and they together form a network specialized in facial processing. In recent years, two neural models were proposed to assess face processing; the Haxby face neural model[32,33] and a modified model for dynamic faces proposed by O'Toole et al.[34]. In 2015, Bernstein and colleagues proposed an updated model integrating the evidence of the models by O'Toole and Haxby.[35]

In fMRI studies, faces were shown to elicit face-selective neural responses in multiple regions along the occipital-temporal cortex. These selective activations were mainly found in the inferior occipital cortex (OFA – occipital face area), the fusiform gyrus (FFA- fusiform face area), and the posterior part of the superior temporal sulcus (pSTS Face Area (pSTS-FA)).[32-35] All three models proposed by Haxby[32,33], O'Toole[34], and Bernstein[35] have described the functional role of these face-selective areas. The main principle of these models is as follows; the 'face processing system' in the brain is composed of two pathways: 1) a dorsal pathway that goes from the OFA to the pSTS-FA and 2) a ventral pathway that also starts at the OFA and projects to the FFA.

The Haxby et al.-model[32,33] is generally considered to be the most eminent, and according to this neural model, the OFA, FFA, and pSTS-FA constitute the core system of face processing (Figure 1). In this model, the OFA plays a central role and gives input to both the FFA and the pSTS-FA.[32,33] In addition, this model indicates that each part has a different role in processing aspects of facial information. The FFA is mainly involved in the processing of invariant aspects of the face, such as facial identity, whereas the pSTS-FA is involved in all the changeable aspects, such as eye-gaze, facial expression, and lip movement.[32,33]

In 2002, O'Toole and colleagues[34] proposed two modifications to the existing model of Haxby et al.[32,33] (Figure 2) These modifications were essential to account for dynamic faces. O'Toole et al. included the pSTS-FA necessity for processing identity information that can be extracted from motion (footnote: only applies to identification of familiar faces for which we have a 'dynamic signature').[34] Furthermore, O'Toole suggested that both pathways (the dorsal and ventral) might interact in a 'structure from motion' analysis, in which dynamic information is processed

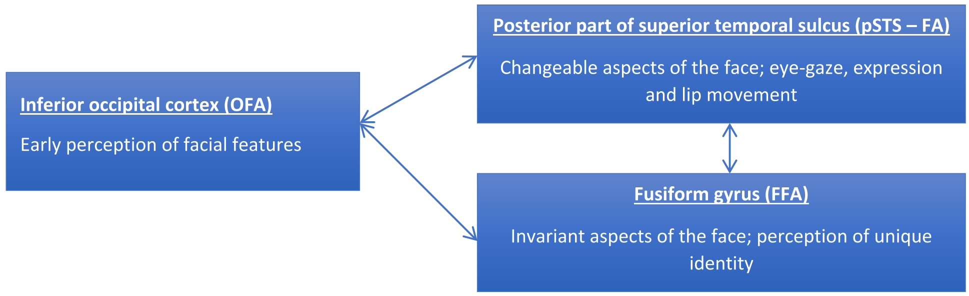

Figure 1 The model of face processing according to Haxby et al.[32,33]. Abbreviations: OFA = Occipital Face Area; pSTS-FA = posterior Superior Temporal Sulcus Area; FFA = Fusiform Face Area.

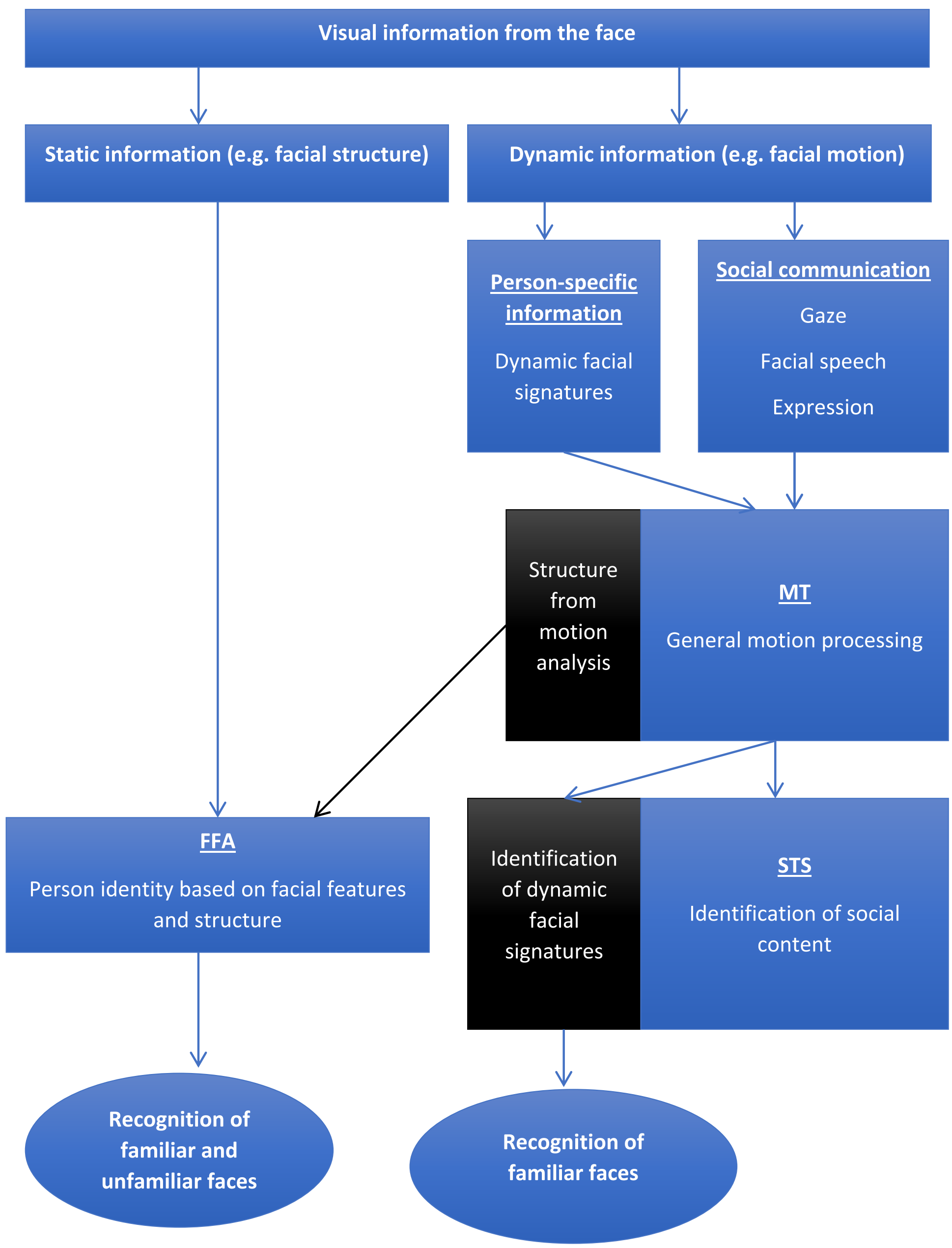

Figure 2 The model of face processing according to O'Toole et al.[34]
Abbreviations: STS = Superior Temporal Sulcus; FFA = Fusiform Face Area, MT = Motion Selective Area.

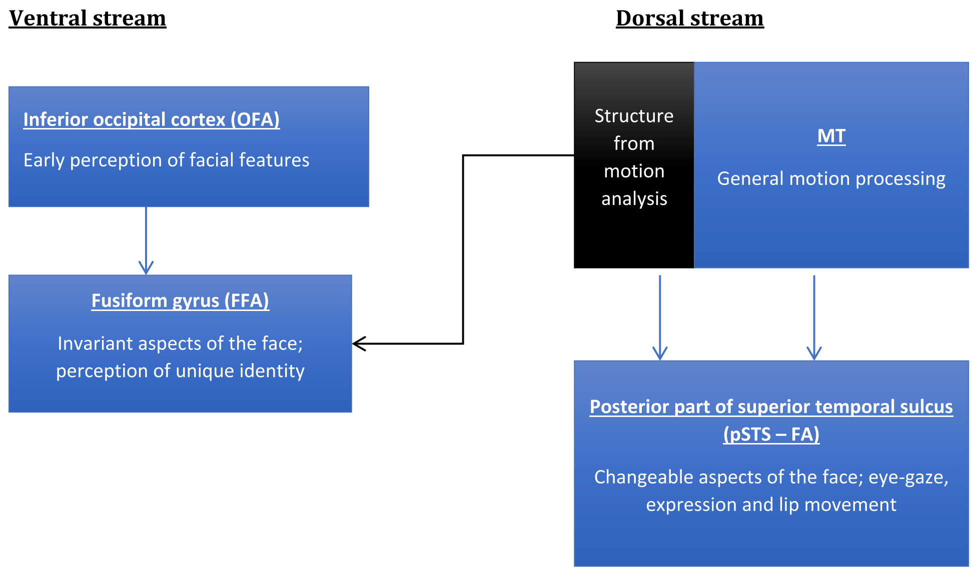

Figure 3 The updated model of face processing according to Bernstein et al.[35]
Abbreviations: OFA = Occipital Face Area; pSTS-FA = posterior Superior Temporal Sulcus Area; FFA = Fusiform Face Area; MT = Motion Selective Area.

(in the motion selective area (MT)) and can be transferred as static form information.[34] A common denominator in both models (Haxby's and O'Toole's) is that the processing of facial expressions is carried out by the dorsal system.[34,35]

Recently, to differ between face form and face motion, a revised model by Bernstein et al. was proposed (Figure 3).[35] The idea behind this model was that the 'face processing system' extracts information (like expression, eye gaze, and head view) from dynamic faces. Moreover, important changes in this model were the realizations that the FFA is also responsive to facial expression and the proven dorsal and ventral system connectivity based on current structural and functional connectivity studies.[35]

Hemispheric specialization and lateralization

In order to understand the potential differences between the right and left hemispheres in terms of facial processing and, therefore, processing of facial features and emotions, we need to compare neuro-anatomy and neurobiology with several known hypothesis. The current belief is that the right anterior temporal lobe's fusiform cortex is the most dominant area in the brain when it comes to the visual analysis of faces.[13] The left anterior lobe is also active but significantly less. This finding is consistent with the impaired ability to recognize and process faces in patients with a right temporal lesion. Further, patients with right hemispheric semantic dementia, which predominately affects the anterior temporal lobe, tend to have more problems with recognizing faces than patients in whose left hemisphere is affected.[36] To further support this finding, fMRI research has shown that the area associated in the brain with recognizing faces in the right anterior temporal lobe is much more active compared to the left anterior temporal lobe.[36]

In general, the human face serves a wide range of biological functions of which the communication between individuals is the most important. Aside from identity and emotional expressions, beauty and health are also processed in the observer's brain. In previous studies by Chen et al.[37] and Zaidel et al.[38], it was found that there is a sex-related left-right asymmetry in facial attractiveness. This was studied by a photograph experiment were left-left and right-right composite photographs were used. Attractiveness of women's faces was rated significantly higher when presented as right-right composites than as left-left composites.[37-39] Additionally, smiling aggravated this cosmetic preference. A smile was significantly scored more pronounced in left-left composite photographs, in both sexes.[38] When considering health perception, right-right composites of women's faces were judged significantly healthier than left-left composites. In men there was no significant difference between left and right.[39]

To understand aforementioned theoretical concepts, 'mirror' and 'true' image also need to be explained. A mirror image is the image people identify with the most, since it is the only image most people see of themselves in their lifetime. Using a mirror or camera creates a distortion in how the face is pictured. The left side is projected on the right side of the mirror or picture and *vice versa*. True image is the image people see when they look at a patient directly and the image is not distorted. To substantiate these claims, research by Mita et al.[40] described that people remember their own facial mirror image and Brady et al.[41,42] showed that, in general, the mirror image is preferred more often than the true image. These findings can be explained by the fact that we get the most visual information about our own face through self-inspection in the mirror. Repeated exposure to an image leads to the acceptance, it is considered 'configurable information' according to Rhodes et al.[43] So, from a theoretical point of view, we have two hypotheses: 1) familiarity hypothesis and 2) a left-right hemispheric specialization hypothesis.

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Clinical studies that assess left and right differences in patients with PFP

In the past years, a few clinical studies tried to translate the earlier mentioned neurobiological concepts to clinical practice. In the field of ocular/facial plastic surgery, the first study was done by Mombaerts et al.[44] in patients with left and right ocular prosthesis. The patients preferred their mirror image and the volunteers significantly preferred the photograph of the patients with the ocular prosthesis on the left side.[44] This study suggested that, in judging the unfamiliar face, the right eye is considered to be of important value in case of abnormality.[44] This concept was broadened by Pouwels et al.[10], who studied left-right differences in patients with PFP in both relaxing[10] and smiling subjects.[9,25] In these studies, it was found that patients with left PFP significantly preferred their mirror image to patients with right PFP. Medical professionals significantly preferred patients with left PFP.[10] In smiling, these results were aggravated[9,25] and supported the earlier mentioned hypothesis of differences in appreciation between left and right paralysis proposed by several studies.[37-39]

The preference for mirror or true image can be explained by the fact that people can get used to their own facial mirror image, whether in a normal condition or in a pathological condition. This adaptation of perception was demonstrated by Webster et al.[45]; after a prolonged viewing of a distorted face, the perceived severity of the distortion is weakened. After this prolonged exposure, a distorted face is perceived as an undistorted face, which is called 'perceptual renormalization'.[45] In clinical studies, it seems that familiarity with their mirror image plays a more important role than left-right attractiveness based upon hemispheric or psycho-neurogenic preference.[9,10]

In a follow-up study investigating the psychological distress in patients with PFP using the Hospital Anxiety and Depression Scale (HADS), Pouwels et al.[8] found that there might be a difference in the occurrence of mild depression between patients with left PFP, compared to right PFP ($p<0.018$). Whether this result is clinically significant remains unclear. Ryu et al.[46] investigated whether there is a difference in quality of life measurements between patients with left and right PFP. They found that, regardless of handedness or hemispheric dominance, the proportion of predominance of the right side of the human face recognition was larger than the left side (71% versus 12%). Furthermore, Facial Distress index and Short-Form 36 (SF-36) scores were significantly lower in patients with right PFP.[46] In conclusion, the universal preference for the right side in human face recognition showed worse psychological mood and social interaction in patients with right PFP compared to left PFP and favored the mentioned hypotheses of facial asymmetry.

Discussion and recommendations

The face is regarded as a major tool in the communication of emotions between individuals and identification of oneself.[47] When evaluating the patient's quality of life outcome after FP, a couple of findings become apparent. FP lowers the attractiveness of the face by about one standard deviation.[7] The QoL of patients with FP is comparable to patients with end stage renal disease. Furthermore, patients with FP feel socially isolated and judged by people.[48]

The role of the face has intrigued anatomists, biologists, psychologists, and artists for hundreds of years. It was in the 1800s that Charles Bell first began to describe the importance of facial expression.[49] Later in the 1800s, the evolutionist Charles Darwin described the six basic emotions as we in the present know them: happiness, disgust, anger, surprise, sadness, and fear.[50] In the 1900s, researchers began looking into the consequences of facial asymmetry on attractiveness and the communication of emotions. Nowadays, there is still marginal robust evidence regarding left and right difference in face processing in the cerebral hemispheres. Further research could give us more insight into the functional anatomy of the brain. Knowing the exact reason for left-right differences would be clinically irrelevant since therapeutic alterations would be equal for both hypotheses. As of today, most of the evidence is theoretically obtained through reasoning and not based on contemporary techniques such as FMRI studies. It will be challenging to translate the current neuro-hypothetical evidence in clinical practice. The first studies done in patients with PFP[8-10,25,46] show promising evidence that there might be a difference in emotional and face processing in the cerebral hemispheres because there seems to be more evidence underlining the hypothesis that emotions are expressed more vividly on the left hemiface in the majority of people.[51-55]. In this context, we have to take into account left and right handedness and thus the differences among dominant hemispheres. In clinical studies, the only study that corrected for left and/or right handedness was the study done by Ryu et al.[46]

In conclusion, this review emphasized that there is neurobiological evidence that there are differences in emotional and face processing of the left and right cerebral hemisphere, whereas it seems that the right hemisphere is superior in emotional processing. To explain the difference, several theories are proposed; 1) familiarity hypothesis and 2) a left-right hemispheric specialization hypothesis. In clinical studies, promising evidence indicates that the QoL indeed differs between left and right FP patients. Finally, this might give differences in the occurrence of depression and altered quality of life. To ensure best care for your patient, it is critical for doctors to be made aware of such differences, so that therapy will be excellent and people with FP can walk the streets, at least internally, smiling.

Conflict of Interest

None

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Author contribution

Conception and design of the study: TT, SC, SP

Drafting and revision manuscript: TT, SC, ES, FWdJ, RL, KI, CB, SM, IS, CE, GVD, DK, SP

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