

# Non-Dominant Hemisphere Stroke and Spatial Neglect: Is Stimulation of Known Hobbies and Cravings a Way to Make Rehabilitation More Effective?

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**Summary.** Stroke is an acute neurologic injury that occurs because of brain ischemia or brain hemorrhage. Improved treatment options for stroke have increased patient survival, but the condition remains the leading cause of long-term disability worldwide. The huge costs and adverse impact of post-stroke disability make improving rehabilitation strategies a priority. Spatial neglect (SN) is characterized as a condition in which patients display insufficient attention to the contralesional side of their surroundings and their own body. It is the most common neurocognitive disorder causing long-term disability, occurring in approximately half of patients with stroke in the non-dominant brain hemisphere. Typical adjacent consequences of SN are difficulties with attention, perception, learning, memory, recognition, motivation, and expression of emotions. Numerous rehabilitation techniques have been designed to alleviate and remediate symptoms of SN. Paradoxically, many of these techniques have not found their way into routine clinical bedside rehabilitation. Rehabilitators may be reluctant to implement unfamiliar strategies, especially if they are new, controversial, or not tested in a clinical environment. In this paper, we propose a hypothesis that better rehabilitation results for stroke survivors with SN can be reached by including patients' hobbies and cravings when training attention towards the neglected space during rehabilitation. Patients' unique cravings and hobbies when used as conditioned cueing may help boost the mesolimbic dopamine system and eliminate hemispheric imbalance, which is thought by many to cause SN.

**Keywords:** neglect, stroke, non-dominant hemisphere, rehabilitation.

To this day, cardiovascular diseases (CVDs) remain the number one cause of death worldwide, without no signs that their number will decline anytime soon. An estimated 17.9 million people died from CVDs in 2016 [1]. Stroke itself is the second most common cause of mortality and the leading cause of long-term disability [1, 2]. Stroke reduces mobility in more than half of stroke survivors aged 65 and over and affects overall quality of life of patients [3]. Due to these ramifications, it is vital to address how treatment and rehabilitation of patients with stroke can be better structured and researched.

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## HYPOTHESIS

Due to the heterogeneous nature of spatial neglect (SN), stroke survivors challenged with this disorder require an individual rehabilitation approach. The loss of motivation and interest towards happenings within the neglected space that patients with SN typically display suggests that it would be beneficial to increase participation and interest during rehabilitation by using patients' hobbies and cravings as stimuli.

## METHODS

A search for recent scientific sources in English was carried out in the international medical databases UpToDate, PubMed, and Elsevier. The following search terms were

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used and combined in various ways: stroke, neglect, non-dominant hemisphere, rehabilitation, and spatial neglect. The identified literature was then reviewed and analyzed in the context of stroke, classical literature on neglect, and patient cases described in well-known literature. In this article, we present a summary of the literature that supports our hypothesis.

## STROKE IN THE NON-DOMINANT HEMISPHERE OF THE BRAIN

Stroke is an acute neurological injury that occurs as a result of the following pathological processes: brain ischemia (thrombosis, embolism, or systemic hypoperfusion) or brain hemorrhage (intracerebral hemorrhage, or subarachnoid hemorrhage) [4]. Ischemic stroke is the most common kind of stroke, accounting for approximately 80% of all cases. Hemorrhagic stroke accounts for about 20% of all strokes [5]. Although the most common presenting symptoms of ischemic stroke are speech disturbance and weakness in one-half of the body, symptoms and their severity vary drastically, from almost non-detectable to so severe that symptoms cause death within a few hours [6]. Presenting symptoms correspond to the area of the brain that loses blood flow.

The brain is one of the largest and most complex organs in the human body. More than 95% of people with right-handed dexterity and more than 70% with left-handed dexterity have left-hemisphere dominance [7, 8]. The hemisphere containing the main language area is called dominant, and the hemisphere without it is called non-dominant. In neurology, it is important to consider the dominance of the hemisphere affected by stroke or any other pathology. This review and analysis of relevant literature will focus on stroke affecting the non-dominant brain hemisphere, and more specifically target SN and ways that can be used to motivate patients with SN during rehabilitation. Speaking of motivation, it is essential to mention the mesolimbic dopaminergic system. The mesolimbic dopaminergic system has been recognized for its central role in motivated behavior, response to various types of reward, and also its role in several other cognitive processes. The mesolimbic dopaminergic system contains pathways that connect the ventral tegmental area in the midbrain to the ventral striatum of the basal ganglia in the forebrain [9]. Functional theories emphasize the involvement of the mesolimbic dopaminergic system in the orchestration of goal-directed behavior and the promotion and reinforcement of learning [10]. Dysregulation of the mesolimbic pathway can cause a hemispheric imbalance that is thought, by many experts, to cause SN.

The non-dominant hemisphere of the brain coordinates many tasks, including problem solving, memory, and reasoning. The deficits vary depending on the location and extent of the brain damage [11]. The most common motor and sensory deficit among patients with non-dominant hemisphere stroke is hemiparesis on the contralesional

side of the body (usually on the left side). Less common long-lasting motor deficits are dysphagia and homonymous hemianopsia. Patients with non-dominant hemispheric damage most commonly have difficulties with attention, perception, learning, memory, recognition, motivation, and expression of emotions. Other, less common deficits include reasoning and problem solving, awareness, orientation, and navigation [12]. Although speech deficits are mainly related to the dominant hemisphere of the brain, stroke in the non-dominant side of the brain can also cause speech and sentence comprehension difficulties [13].

The main issue that complicates the rehabilitation of many patients with non-dominant stroke is anosognosia, or the situation where patients minimize or even act utterly ignorant of their impairments [14]. Because of anosognosia, patients do not feel frustrated or upset when they are unable to perform tasks, they were previously able to do. This deficit complicates rehabilitation greatly.

SN may, as mentioned previously, interfere with the success of rehabilitation. The disorder is considered more common, severe, and persistent after injury to the brain's non-dominant hemisphere, but it also occurs due to dominant hemispheric strokes [15]. Clinical manifestation of SN is associated with a defective awareness of space located on the contralesional side of the brain injury [16]. The presentation of SN is heterogeneous and involves different clinical subtypes. SN is most common in the visual modality, which is labeled *visual neglect* (VN). Patients with VN display incapacity to detect and/or respond normally to stimuli provided within the contralesional visual field [17]. In *somatosensory neglect* or *tactile neglect*, patients fail to notice tactile, thermal, or painful stimuli applied to the contralesional body side sufficiently. Patients can also make stimuli localization errors or mistakes in evaluating the spatial position of their limbs [17]. Finally, *motor neglect* transpires as a failure to use the contralesional limbs even in the absence of primary motor deficits [18]. Patients with motor neglect may, in the worst cases, behave as if they were hemiplegic and refrain from using their affected limb during bimanual activities. The other two subtypes of SN are *personal* and *extrapersonal* neglect. Personal neglect is recognized when patients fail to explore or be aware of the contralesional part of their own body or face [19]. Extrapersonal neglect defines patients' ignorance of the environment further away from them.

## NEGLECT AND REHABILITATION

Rehabilitation plays a vital role in stroke survivors and their ability to get back to everyday life or adapt to new circumstances. In recent years, the understanding of neuroplasticity and functional recovery has grown significantly, and special rehabilitative training is in many instances targeted at enhancing the processes of neuronal plasticity [20]. However, the success of rehabilitation varies greatly. It depends not only on the severity of the stroke

and its treatment, but also on presenting symptoms. Thus, some symptoms complicate rehabilitation more than others. Patients with SN often require more extended rehabilitation stays than patients without this disorder. On average, patients with SN stay in inpatient rehabilitation facilities for one week longer than stroke patients with sensory-motor deficits [21]. Studies show that the duration of rehabilitation and its success depends on the type of SN and its severity [21]. Because SN entails a disruption of several cognitive processes, different neuropsychological deficits may be observed across patients. This variety of symptoms makes it impossible to rehabilitate patients with SN using only a single technique [22, 23]. Therefore, several different rehabilitation approaches have been developed to improve SN, such as visual scanning training, where the patient is encouraged to make eye- or head movements towards the contralesional side and limb activation therapy, where the main idea is to stimulate the affected limb and direct attention towards the neglected hemispace [24, 25]. Other techniques include specialized devices such as neglect alerting devices that, for instance, may make a noise that only can be turned off by using the neglected side of the body [26]. Also, functional electrical stimulation of the neglected upper limb is a bottom-up approach that can be used to induce passive movement. This treatment has proved to increase target detection in visual scanning tasks [27]. One of the most promising rehabilitation techniques, however, is prism adaptation. The idea of prism adaptation is that while patients wear deviating prisms, visual targets appear displaced, so when the patients point to them, they get feedback that they have pointed too far. After removing prisms, patients make rapid ballistic movements and usually show deviation to the neglected side [28]. Research studies have shown that prism adaptation can modify various aspects of neglect behavior. To exemplify, somatosensory extinction [29, 30], visual-verbal measures [31], and postural control [32] have improved significantly after prism adaptation. However, not all studies have shown consistent benefits [33].

A growing amount of evidence indicates that increasing attention to the contralesional side in patients with SN is encouraged by providing context-related stimuli or using stimuli that infuse emotional responses [34, 35]. The clinical significance of strong emotional cues was first observed by the renowned neurologist Walther Russel Brain who described in the late 1940'ies how a patient with SN used her wedding ring placed on her left finger to recognize her neglected extremity [36]. Many studies have since shown that stimuli that evoke fear, joy, and excitement boost attentional processing, even within the contralesional side [37, 38]. In a more recent qualitative study, a young mother with SN could hold her infant baby with her left arm, while, in contrast, she consistently dropped other not as important items when using her left arm [39]. Emotionally salient reinforcement can increase patients' motivation to direct their attention to items or events within the neglected space [34, 38]. It is, therefore, not surprising that stimulation with solid emotional components such as

positive intonation of voices, emotional prosody in facial expressions, colorful stimuli, rewards, and music are increasingly being investigated in SN studies [40–43].

However, we find it intriguing that hobbies and cravings of patients, as far as we know, have not received explicit attention as clinical rehabilitation strategies. We suggest looking at mild cravings in the context of SN rehabilitation, which provides an opportunity for a more productive and novel identification of person-bound stimuli that have high emotional salience or even produce a bodily state of satisfaction. There is no clear definition of craving, but it is usually understood as a personal longing or subjective desire or wanting. To simplify, a craving is personal and subjectively linked to what the individual wants.

The concept “craving” is often associated with a pathological state of desire, such as in the context of smoking, alcohol, or drug abuse, as well as negative mood, increased reaction time, and anything that interfere with cognitive processing of stimuli [44]. In contrast to such pathological cravings, we look at mild cravings as something that, via salience and meaningfulness of stimuli, helps patients sustain attention throughout rehabilitation and become more vigilant [45]. Several studies have shown that encompassing issues such as computer games that trigger reward circuits in the mesolimbic dopamine system in rehabilitation lead to improvements in SN, both related to tonic and phasic alertness [46, 47]. It is, however, surprising that various computerized methods have not been coupled with more personalized unique stimuli to help capture patients' attention and improve their response time within the neglected space. Also, it is surprising that known hobbies and cravings are underused in clinical rehabilitation. This lack of use may be partly explained by difficulties in researching the effects of this approach in patients with SN. Evaluating the effects of cravings and hobbies unobtrusively in a clinical environment is indeed challenging. Virtual reality, mobile eye tracking devices and functional brain imaging may provide pertinent ways of testing our hypothesis. Mobile eye-tracking, in particular, provides unique opportunities for assessing covert attention, what attracts patients' attention during daily rehabilitation, and how effective “mild cravings” and cues from patients' hobbies are when they are either combined with conventional rehabilitation strategies or provided in isolation. In patients with SN, eye-tracking during daily activities may reveal how they organize their actions and their perceptual limitations, e.g., by providing data such as differences in visual exploration and fixations between left and right hemifields. Also, mobile eye-tracking glasses can reveal how patients move their gaze within their visual field, and therefore can be used to assess the benefits of training [48].

## DISCUSSION OF THE HYPOTHESIS

Evidence shows that patients with SN spend more time in rehabilitation facilities and do not achieve the same im-

provement as stroke patients without the disorder. This itself suggests that traditional rehabilitation techniques are insufficient. Patients with SN are sometimes discharged without completing rehabilitation programs because they are considered non-cooperative. As a result, many of them are discharged to nursing homes without getting a fair chance to improve their independence and quality of life. Although there are many rehabilitation techniques for patients with SN, many of them require special equipment or training of staff before implementation. This poses a problem because many rehabilitators worldwide are unfamiliar with neglect rehabilitation and many of the techniques used are new, controversial, and have not yet fully proven their effectiveness. In this article, we propose the hypothesis that better rehabilitation results among stroke survivors with SN can be achieved by including patients' hobbies and cravings when training attention towards the neglected space during rehabilitation. When used as conditioned cueing, patients' unique cravings and hobbies can help boost the mesolimbic dopamine system and diminish the hemispheric imbalance, which is thought by many to cause SN. The uniqueness of cravings and hobbies calls for divergent ways of establishing viable stimulation and testing its effectiveness, such as mobile eye-tracking, virtual reality (VR), and functional brain imaging. This hypothesis requires further studies and input from both neurology and rehabilitation doctors.

## CONCLUSION

Since stroke is the leading cause of long-term disabilities worldwide, it is vital to address how rehabilitation can be improved. The main goal should be to customize rehabilitation according to each stroke patient's unique disabilities. Although SN is common in stroke survivors and is a known hindrance for successful rehabilitation outcomes, there is insufficient data to draw firm and reliable conclusions about rehabilitation strategies. Exceedingly more studies focus on cognitive rehabilitation and SN. However, the effectiveness of cognitive rehabilitation interventions to reduce the disabling effects of SN and increase independence remains unproven and new approaches are needed both in research and clinical practice. Our hypothesis adds substance to the argument that more focus should be put on SN rehabilitation to establish the best ways to reduce disability and improve the quality of life of patients with SN. The strategy we propose does not require expensive procedures that are difficult to apply. On the contrary, patients' hobbies and cravings can be deliberately used without extensive barriers and costs. Summarizing our hypothesis, we can recommend collecting necessary detailed and comprehensive anamnesis of the patient's previous hobbies and possible (pathological) dependencies at the beginning of rehabilitation.

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## NEDOMINUOJANČIO PUSRUTULIO INSULTAS IR ERDVINIS NEGLEKTAS. AR ŽINOMŲ POMĖGIŲ IR POTRAUKIŲ STIMULIACIJA YRA BŪDAS PADARYTI REABILITACIJĄ EFEKTYVESNĘ?

### Santrauka

Smegenų insultas – tai ūmus neurologinis pažeidimas, atsirandantis dėl smegenų išemijos ar kraujo išsiliejimo į smegenis. Pagerėjusios insulto gydymo galimybės padidino pacientų išgyvenamumą, tačiau ši būklė lieka pagrindine ilgalaikio neįgalumo priežastimi visame pasaulyje. Didelės insultą išgyvenusių, tačiau nuo ilgalaikio neįgalumo kenčiančių pacientų priežiūros ir gydymo sąnaudos skatina skirti vis didesnę dėmesį rehabilitacijos strategijų tobulinimui. Erdvinis neglektas apibūdinamas kaip būklė, kai pacientas nekreipia dėmesio į aplinką ir savo kūną, priešingose pažeidimui pusėje. Tai labiausiai paplitęs neurokognityvinis sutrikimas, sukeliantis ilgalaikę negalią, pasireiškiantis maždaug pusei pacientų, patyrusių smegenų insultą nedominuojančiame

smegenų pusrutulyje. Erdvinis neglektas apibūdinamas dėmesio, suvokimo, mokymosi, atminties, atpažinimo, motyvacijos ir emocijų raiškos sutrikimais. Šiems simptomams palengvinti buvo sukurta daugybė rehabilitacijos programų ir metodų, tačiau daugelis jų nepasiekė kasdienės klinikinės rehabilitacijos. Reabilitologai dažnai vengia nežinomų rehabilitacijos strategijų, ypač jei jos yra naujos, brangios, komplikotos, prieštaringos ir netestutos klinikinėje praktikoje. Šiame darbe keliama hipotezė ir pateikiamas jos pagrindimas, kad geresnių rehabilitacijos rezultatų tarp išgyvenusiųjų insultą ir kenčiančių nuo erdvinio neglekto galima pasiekti, į reabilitaciją įtraukiant pacientų pomėgius ir potraukius, juos panaudojant paciento dėmesiui atkreipti į ignoruojamą aplinką ar kūno dalį. Unikalių pacientų potraukių ir pomėgių įtraukimas į jų reabilitaciją gali padėti suaktyvinti mezolimbine dopaminerginę sistemą, pašalinti pusrutulio disbalansą, kuris, daugelio manymu, sukelia erdvinį neglektą.

**Raktažodžiai:** neglektas, insultas, nedominuojantis pusrutulis, reabilitacija.

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