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# The Influence of Colored Running Lights on Route Choice – Dynamic Guidance and Affordance

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***Abstract*** **-** In case of fire in a subway system, guidance to the safest emergency exit plays an important role for passengers' safety. Dynamic route guidance by colored flashing lights and strobe lights at emergency exits has been tested. Yet, the effects of dynamic lights to support route choices in subway systems can still not be determined.
The focus of this study was the sensory, cognitive and functional affordance of green and red running lights in the context of evacuation in subway systems to guide passengers into a safe area. The paper presents data from a study about route choices supported by red and green running lights. 15 different designs including three different subway intersections were presented. Each design showed a different setup with or without moving colored lights. The participants were asked to make a decision about the safest direction in case of evacuation.
Data analysis focuses on the effects of the moving colored lights on route choice and the concept of affordance. Overall the green running lights had a strong positive effect on the route choices and supported the effectiveness of sensory and cognitive affordance. Green running lights were even able to decrease functional affordance by architectural design elements. Green running lights should be considered as a suitable color and dynamical feature to guide users to a safe area in an unambiguous way. Red running lights were able to guide users but led to more indecisive route choices because of interaction of cognitive and functional affordance. Because time and unambiguous information in case of an emergency might be crucial for a safe evacuation, it is not advisable to use red running lights in a dynamic guidance system.

***Keywords*****:** running lights, dynamic guidance, green, red, evacuation, affordance, route choice

## 1. Motivation of the study and introduction to the concept of affordances

Dynamic route guidance by colored flashing lights, strobe lights [1] or dynamic signage [2] at emergency exits has been tested Yet, the effects of dynamic lights to support route choices in subway systems can still not be determined. Dynamic guidance might be helpful especially in situations where the common path of travel is blocked, e.g. with smoke or debris, or when passengers should be guided to a certain exit. The study presented here is part of a research project on subway fire safety. It focuses on the effects of running red and green lights in the context of subway systems because these colors are frequently used in the context of safety (green for safety and red for danger [3]). Recommendations for practitioners should be deduced, so passengers can be supported in evacuations to choose quickly for the safest path or exit.

The concept of affordance was used as a theoretical frame for the study. "Affordance" means that certain characteristics of an object are related to certain actions and knowledge of a user, e.g. a flashing red light could help to focus attention, or a disgusting smell might lead to not eating a fruit. The theory of affordances was originally published by Gibson, e.g. [4]. Most often the concept of affordances is used to evaluate support of users by design elements and to evaluate design processes. The application of the concept has been discussed widely, e.g. in system interaction design [5, 6] and lately in the context of evacuations [7, 8]. In the user-centered design view by Norman [9] affordances result from a mental presentation of things based on knowledge and past experiences to the perception of certain objects, e.g. the use of stairs to go up. Thereby, affordances reflect relationships between objects and users. Researchers discuss mostly four kinds of affordances [5, 7]: Sensory affordance, cognitive affordance, functional affordance and physical affordance. This differentiation is made to put emphasis on the role of affordances to support users during interactions, user processes and the actions of users in task performance (for a detailed discussion see [5]). *Sensory affordance* helps users with sensory actions (e.g

seeing, hearing, or feeling), e.g. detecting information by drawing attention to a moving light. In this study, sensory affordance of green and red running lights was tested by route choices of participants confronted with different running lights. *Cognitive affordance* as a design feature enables interpreting the intended function of a design element, e.g. in this study, understanding the meaning of a green running light to lead to a safe exit. *Functional affordance* combines sensory and cognitive affordance and allows identifying usage and utility of an object. Users are supported to achieve a desired goal by certain characteristics of an object, e.g. the functional affordance of stairs: For evacuating safely from a subway station it is useful to take the stairs upstairs to get to the next floor/ outside". *Physical affordance* helps users with their physical actions, e.g. the form of a handrail (round, smooth) helps keeping a strong grip while walking. Physical affordance was not included in the study. Participants made route choices in a computer-based setting and were not supposed to use physical design elements like handrails.
All forms of affordance interrelate to each other and are not always distinct, as scientific discussions reveal. The focus of this study was the sensory, cognitive and functional affordance of green and red running lights in the context of evacuation in subway systems to guide passengers into a safe area.

## 2. Method

### 2.1 Study design

The effects of green and red running lights, pointing into a certain direction at three different intersections in a subway station, were analyzed by the route choices of participants. The intersections were presented on a laptop computer as motion pictures in graphics interchange format (GIF). Pictures were taken from a real setting, a subway station in Berlin, but they were digitally changed for the purpose of the study. Each picture was designed without any lights, and with either green or red running lights. The running lights were presented moving (with a frequency of 200 ms) either right or left. In total, 15 different designs were used (Table 1). Examples of the designed intersection with green and red running lights are shown in the figures 1 to 6.

| Intersection | | Color of light | Direction of running light |
|---|---|---|---|
| Intersection 1 | Baseline (no lights) | Green | Left ← |
| | | | Right → |
| | | Red | Left ← |
| | | | Right → |
| Intersection 2 | Baseline (no lights) | Green | Left upstairs ↖ |
| | | | Right along platform → |
| | | Red | Left upstairs ↖ |
| | | | Rightalong platform → |
| Intersection 3 | Baseline (no lights) | Green | Left ← |
| | | | Right → |
| | | Red | Left ← |
| | | | Right → |
| Number of items | 3 | | 12 |

Table 1: Intersections designs for intersection 1 to 3, no lights, color of light (green or red) and directions of running lights.

The study was carried out in a real subway station accompanying another field study (see PED 2016, paper 66 Hofinger et. al, in press [12]). In the beginning, informed consent was obtained from all participants. Participants filled in a questionnaire about demographics including their experience with subway systems. The participants were then seated in front of a laptop computer. The pictures and GIFs of the intersections, route choice alternatives and additional questions were presented in a digital format. Participants were asked to make a decision about the safest route. For each picture, participants had to choose between two alternative directions, e.g. to turn right or to go upstairs. They had to enter their route choice via the keyboard. The three intersections without any lights were presented first in randomized order as a baseline and then the intersections with green or red running lights (GIFs) were presented in a randomized order. Finally, the participants answered a questionnaire about the green and red lights.

### 2.2 Participants

31 participants took part in the study. 25 participants were (master or bachelor) students from several specialities, e.g. geography (19) or social sciences (2); 6 participants were postgraduates, e.g. working as a musician, or architect. All participants were Germans. The whole study was conducted in German language. The age of the participants ranged from 20 to 31 years with an average of 24.87 (*SD* = 2.86).

Two of the participants were left-handed (6.5%), 95.5% were right-handed. Participants all stated that they had normal or corrected eye vision.

# 3. Results

## 3.1 Baseline

To allow further comparisons, the three pictures of intersections without running lights were statistically analyzed. Results were considered as a baseline, without influence by light, for the route choices of the participants. Results of tests of binomial-distribution showed no significant difference between the choice of right vs. left in intersection 1 (Fig.1). Furthermore, no significant difference between the choices of moving upstairs vs. along the platform in intersection 2 was found (Fig.2). Because of the lack of preferences, for intersection 1 and 2 both route choice alternatives were considered equally attractive to the participants. No functional affordance was found for these intersections.

A statistically significant difference was found for intersection 3 (Fig. 3). Participants´ options werea left turn to a staircase not clearly visible or to walk up the stairs at the right side. Here, an effect of functional affordance of the visible staircase was found: 23 of 31 participants preferred to walk upstairs.

Fig. 1: Intersection 1 in a subway station without moving lights (baseline). Possible routes are equivalent (no functional, cognitve or sensory affordance leading to any side).

Table 2: Frequencies and percentage of route choices (left or right) for the baseline of intersection 1 (in Fig.1).

| **Intersection 1** | Frequency | Percentage |
|---|---|---|
| Left direction | 12 | 39% |
| Right direction | 19 | 61% |
| Total | 31 | 100% |

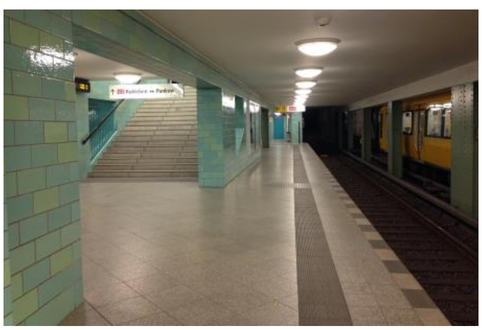

Fig. 2: Intersection 2 without any lights. The two alternatives (left/upstairs; right/along the platform) have different cognitive and functional affordances.

Table 3: Frequencies and percentage of route choices (left or right) for the baseline of intersection 2 (in Fig.2).

| **Intersection 2** | Frequency | Percentage |
|---|---|---|
| Left direction/ upstairs | 13 | 42% |
| Right direction/ along the platform | 18 | 58% |
| Total | 31 | 100% |

Fig. 3: Intersection 3 without any lights. The two alternatives (left; right/upstairs) have cognitive and functional affordances.

Table 4: Frequencies and percentage of route choices (left or right) for the baseline of intersection 3 (in Fig,3).

| **Intersection 3** | Frequency | Percentage |
|---|---|---|
| Left direction | 8 | 42% |
| Right direction/ upstairs | 23 | 58% |
| Total | 31 | 100% |

In the following examples of the designed intersection with green or red running lights are shown accompanied by frequency tables of the route choices of participants.

Fig. 4: Examples of intersection 1 with green running lights moving to the right[1] direction.

Fig. 5: Examples of intersection 2 with red running lights moving upstairs.

Table 4: Frequencies of route choices separated by color and direction of running light for intersection 1.

| Intersection 1 | Route choice by participants (frequencies) | |
|---|---|---|
| **Color and direction of light** | Left direction | Right direction |
| Green/light running to right direction | 28 | 3 |
| Green/ light running to right direction | 3 | 28 |
| **Total** | **31** | **31** |
| | | |
| Red/ light running to right direction | 19 | 12 |
| Red/ light running to left direction | 20 | 11 |
| **Total** | **32** | **30** |

Table 4: Frequencies of route choices separated by color and direction of running light for intersection 2.

| Intersection 2 | Route choice by participants (frequencies) | |
|---|---|---|
| **Color and direction of light** | Left direction/ upstairs | Right direction/ along the platform |
| Green/light running to right direction | 5 | 26 |
| Green/ light running to right direction | 20 | 11 |
| **Total** | **25** | **37** |
| | | |
| Red/ light running to right direction | 14 | 17 |
| Red/ light running to left direction | 13 | 18 |
| **Total** | **27** | **35** |

Fig. 6: Examples of intersection 3 with red running lights moving left direction.

Table 4: Frequencies of route choices separated by color and direction of running light for intersection 3.

| Intersection 3 | Route choice by participants (frequencies) | |
|---|---|---|
| **Color and direction of light** | Left direction | Right direction/ upstairs |
| Green/light running to right direction | 5 | 26 |
| Green/ light running to right direction | 26 | 5 |
| **Total** | **31** | **31** |
| | | |
| Red/light running to right direction | 10 | 21 |
| Red/ light running to left direction | 16 | 15 |
| **Total** | **26** | **36** |

[1] Lights in the pictures show the starting position (brighter dots) of the moving green or red running lights.

### 3.2 Evidence for the guidance effect of the green running lights

Overall the green running lights had a strong positive effect on the choices of direction the lights pointed to and proved the effectiveness of the cognitive affordance of the green running light. Results support previous findings on the color green as “go” or “safe” [3]. The effect of the green lights was analyzed by comparison of the baseline and participants’ route choices for the intersections with green running lights (McNemar test). For intersection 1 and 2, where the baseline showed no preference for one of the alternative routes, participants’ route choices changed significantly into the direction of the green running lights. This effect was found independently of the direction of the green running light: Participants chose the direction of the running lights no matter if the green light pointed to the right or left.

An even stronger effect was found for intersection 3 where in the baseline participants preferred the stairs at the right side. If the green running light moved to the right, the positive effect increased and more participants decided to walk upstairs. The effect, also named redundancy gain [10], can be explained by congruence of the cognitive affordance of the green light and the functional affordance of the viewable staircase. If the green running light moved to the left, most participants changed their mind compared to the baseline and chose the left direction.

### 3.3 Interference of green or red running lights and affordance

The running lights, independent of the color, had an effect on the choices but the red running lights conflicted with the functional affordance of architectural elements presented in the GIFs, e.g. staircases. The effect of the running lights was analyzed by comparison of the route choices by participants for the intersections with green against red lights (McNemar tests).

For intersection 1, participants’ choices to follow the green lights were significantly clearer than to follow the red running lights. For some participants, the red running light even led to a decision against the direction the red light pointed to. The color red represents “stop” or “danger” [3]. So, it can be concluded that the conflict between the cognitive affordance of the color red and the movement of the light in a certain direction (sensory and cognitive affordance) lead to a less definite decision.

In intersection 2, participants’ choices to follow the green lights were significantly clearer than to follow the red running lights. The cognitive affordance of the green lights led to a more definite decision than for the red lights. An interaction between cognitive and functional affordance and the red running light was found. When the red light moved upstairs, participants more often chose to walk along the platform, which means to use the functional affordance rather than to walk upstairs.

In intersection 3, participants’ choices to follow the green lights were significantly clearer than to follow the red running lights. The cognitive affordance of the green light also led to a more definite decision than for the red light. Even though more participants decided to follow the red running light when it moved to the right/upstairs than in the baseline, this effect decreased when the red running light moved to the left. In this case, no difference was found between both alternatives. The functional affordance which was found in the baseline (walk upstairs) was decreased by the meaning and movement of the color red (sensory and cognitive affordance). The green light (cognitive affordance) offered a stronger implication to a safe route than the viewable staircase (functional affordance) and led participants to modify their route preference.

### 3.4 Effects of handedness

Participants were also asked about their handedness to examine a potential effect on the route choices as shown e.g. in [11]. Right- or left-handedness had no significant effect on the route choice of the participants. Because only 6.3 % of the participants were left-handed, the influence of handedness was considered non- reliable and not further examined.

## 3. Discussion and Conclusion

The study included mostly students and only a few working people. Only a few intersection designs were presented for the study. To establish a generalization of the findings, further research will include different participant groups, e.g. children, differences in gender and cultures, and more intersection designs. Color blindness was not included as exclusion criterion but should be considered in future studies.

Red running lights were able to guide users but led to more indecisive route choices because of interaction (and/or interference) of cognitive and functional affordance. Red running lights seem to give more guidance than no lights but the meaning of the color code red might strongly interfere. Because time and unambiguous information in case of an emergency might be crucial for a safe evacuation, it is not advisable to use red running lights in a dynamic guidance system. The results of the study match positively with findings from color research and might help to support cognitive affordance to choose the safest exit route.

Overall the green running light had a strong positive effect on the route choices and supports the effectiveness of sensory and cognitive affordance. Green running lights were even stronger than functional affordance proposed by the design of architectural elements in the intersections. Green running lights should be considered as a suitable dynamical feature to guide users to a safe area in an unambiguous way.

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