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A GUIDE FOR FIXED SAFETY PICTOGRAM SIGNAGE IN WORKPLACES BASED ON HUMAN FACTORS APPROACH

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Abstract The aim of this paper is to propose a practical guide for application of fixed safety pictograms in workplaces. Initially, the two main relevant models in literature are combined to analyze the cognitive stages and functions of information processing and communication, from human factors' aspect. Findings of existing research and analysis are applied in all stages also incorporating findings from Risk Perception and Human Reliability research. All findings are then synthesized in a guide including the steps of target-behavior selection, pictogram design and location. Although a lot of issues remain to be researched, a number of practical guidelines is proposed, aiming to enhance the process of selection, design and location of safety signs by incorporating aspects of human factors.

Keywords: Safety signs; human factors, human reliability, risk perception.

1. INTRODUCTION

Safety signage is an important measure for safety in workplaces. It is ranked in the third level of hazard control hierarchy [1], after design and guarding. It can act in support of the previous levels or even as the ultimate measure for the residual risk that has not been eliminated by design and guarding.

The main purpose of safety signs is to provide information and act as a reminder [2], as well as to sometimes share responsibility with workers or serve the "right to know" [3]. Some further functions of safety signs are discretion (e.g. of a dangerous surface painted in different color), spatial demarcation (e.g. of a dangerous area), awareness raising (alert) as well as simply compliance to safety regulations that dictate safety signage.

In order to serve all these functions, safety signs have to effectively communicate their messages to the main recipients, i.e. workers. There has been significant research in this aspect through the lens of human factors. According to human factors discipline, in order to achieve its purpose (i.e. impose a certain target-behavior), a sign has to be successfully sensed, detected, perceived and cognitively processed.

This multi-stage dependence of success unavoidably bounds the reliability of holistic stimulus-response (behavioral) experiments, as not all information-processing stages can be examined at the same time: a certain behavior might be affected by different parameters in different

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stages. Nevertheless, important research so far has focused and studied some discrete stages, either by sign recognition experiments or monitoring of physiological parameters, such as electroencephalogram data [4] and eye tracking [5].

Some studies ([3], [2]) overview all stages of human information processing, also providing important overall suggestions and clues for signage in general. This paper aims to provide a certain practical guide, based on findings and clues of existing research and also incorporating more analytically the aspects of human error and subjective risk perception, in order to assist practical implementation of safety signage, incorporating human factors approach. To do so, it inevitably has to narrow the scope in a limited but important kind of safety signs that present common features. Of course, existing research has not explored all issues and situations; such issues and situations are also presented and discussed qualitatively.

This kind of signs examined in this paper is fixed visual safety pictograms (excluding fire protection and emergency pictograms) based on the following common features:

- Solely visual stimuli.
- Stimuli of stable salience (they do not change in shape, size, brightness or position).
- Important cognitive effort. Unlike demarcation (e.g. continuous yellow lines) or discretion signs (e.g. red/white or yellow/black delineation), pictograms require recognition and translation with some important use of cognitive resources.
- Detected and processed before the occurrence of risk. Therefore, emergency and fire protection signs are excluded, as their function is important during the occurrence of risk.

Namely, the signs included in this study are:

- Warning. Black pictograms in yellow background and a black triangle frame, informing about a workplace hazard, e.g. “hot surface”.
- Mandating. White pictograms in circular blue background, mandating a certain safe behavior (e.g. “use hand protection”).
- Prohibition. Black pictograms in white background, surrounded by circular red frame, prohibiting a certain unsafe behavior (e.g. “do override conveyor”).

This study will focus on pictograms only, which is considered as a more effective way of presentation for various reasons, such as language diversity, time required to read, space requirements (particularly in many languages), as well as that pictograms are faster to be perceived [6] and easier to remember [7].

Having a purpose-oriented view, it is important to set realistic goals, such as when (and how) we should aim and expect the sign to be detected and processed. Since people do not seek for safety signs [2] and the nature of the examined signs does not aim to inform at the moment when risk occurs (e.g. unlike alarms or emergency signs), we should neither aim or expect workers to be distracted when performing their tasks to read safety signs, it is expected and aimed that these signs will be perceived and detected before the occurrence of the risk and in time of low workload.

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This is in accordance to evidence [8] indicating that such signs are more effective when presented in advance. For the same reason, signs rarely encountered (e.g. safety signs in support facility rooms) are also excluded from this study. Moreover, the permanent presence of these signs increases the probability to meet these favorable conditions (low workload) at some time, as in times of low workload people might look for further stimuli [9], which might be an opportunity for such less prestigious stimuli (as safety signs) to find their way to the working memory.

2. METHODOLOGY

Application of human factors approach to safety signs usually takes place using the C-HIP [10], which is a handy model that summarizes all main stages of human information processing and the communication cycle. However, for the kind of analysis that is attempted in this paper, a more analytical framework is also required, allowing for more sub-stages and distinct examination of attention resources and memory modules, namely:

- Attention resources that include all available cognitive resources for processing. They can vary for different individuals and different situations.
- Sensory memory, which sustains stimuli for a short period.
- Short-term memory, which stores few stimuli for a short period as a filter separating more important information that is sent to working memory from all other information that is rejected.
- Working memory, a limited capacity storage that interacts with attention resources to process important information.
- Long-term memory of large capacity, where important information is stored after being processed in working memory, where it is also retro-fed when required.

Therefore, C-HIP is combined with the model presented by Wickens and Carswell [11] with some further modifications that will serve the purpose of this certain analysis:

- A link is set (dotted line) between attention and sensation, because of the visual nature of the stimuli. Unlike for sounds and odors, sensation of visual stimuli are sometimes dependent on attention (deliberate direction of gaze).
- Sensory and short-term memory are also added to provide a holistic presentation of the process.
- The interaction between working memory and long-term memory is also added, excluding the phonological loop, as only visual stimuli are included. Therefore, the central executive of working memory coordinates visuospatial sketchpad (interacting with visual semantics of long-term memory) for interpretation of the visual stimuli and episodic buffer (interacting with episodic long term memory) for visual recognition of the stimuli, based on existing (real or envisaged) experiences.

The stages of the two models do not coincide. Mental stages of C-HIP include different cognitive processes and, therefore, C-HIP includes loops in almost all its stages. It has to be emphasized that this is not a new general proposed model, but only a case-specific combination of the model of Wickens and Carswell [11] and C-HIP on the features of the examined safety pictograms.

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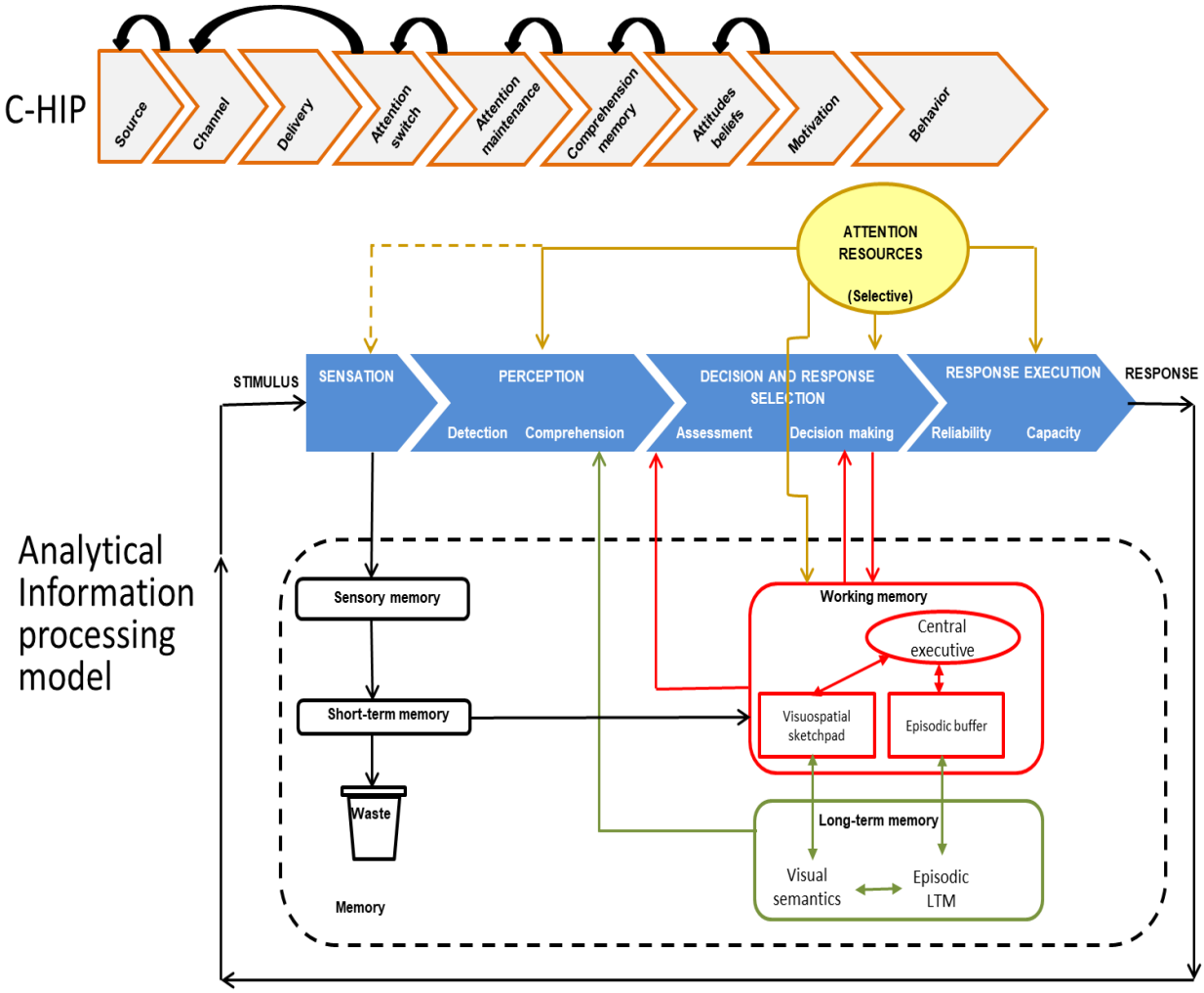

Figure 1. A combined information processing model for fixed safety pictograms.

The whole process is bidirectional: bottom-up, where information processing is driven by stimuli and top-down, where it is driven by experiences and intent (expectations, requirements, etc.) of the individual.

In the next sections, all stages will be analyzed for the specific pictograms, divided in the following sub-stages, in order to facilitate analysis and incorporation of further principles:

- Sensation: The stage where the sign is found in the visual field of the worker.
- Perception: The stage where information already sensed by eyes is initially detected (detection) and understood (comprehension).
- Decision and response selection: The stage where the comprehended information is evaluated (assessment) and decision is taken for action (decision making).
- Response execution: The stage where resources are applied (capacity) and proper action is performed (reliability).

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After this analysis, a synthesis will follow, where findings of all stages will be sorted in the functions of selection, design and location of the pictograms in order to provide a certain methodology for application of this kind of signage.

3. RESULTS

3.1 Sensation

The stage of sensation is sometimes difficult to distinguish from detection in terms of affecting factors. However, it is important to examine separately some factors of physical visibility from factors directly linked to attention, particularly in safety pictograms, where attention is not granted.

Regarding the four characteristics of stimuli [12], only location (e.g. position, clutter, etc.) and intensity (e.g. brightness, contrast) have to be further examined in the certain case, as sensory modality (visual/pictogram) and duration (permanent) are granted for this kind of safety signs. The effect of location and intensity is not independent, as one could compensate for the other to some degree.

A basic requirement for sensation (and a pre-requisite for all other stages) is to have the pictogram within the visual field of the worker. Different colors have different features in this respect [13], as red and green can be discriminated only 20-30° into the periphery, whereas yellow and blue can be discriminated up to 40-60°. Hence, prohibition pictograms need to be closer to the center of the visual field of the worker, compared to warning and mandatory signs. In any case, the usual area of presence of workers has to be identified and signs have to be placed within these angles.

Another obvious characteristic of location is the size of the pictogram in relation to the distance between the viewer and the posting area. Generally, granted that critical minimum size is exceeded, the bigger and closer, the more likely to be seen.

“Clutter” is a common term in scientific and grey literature about anything that could interrupt or constrain visibility. It also includes anything that could add unnecessary information that will obstruct perception or comprehension, which will be examined in later stages. A number of such clutter sources can be described as:

- Improper surface for posting signs, including color, dirt, other posted information, etc.
- Objects obscuring visibility (interposition).
- Dirty or worn-out signs. There are studies investigating the effect of tear and wear on recognition of safety signs [14]. However, generally, visibility due to wear is qualitatively assessed.

Regarding intensity, the most important parameter is brightness. Detailed hue specifications (RAL color standard) are provided in standards (e.g. ISO 3864-4:2011), however, it is common to find DIY printed signs in workplaces keeping only the basics of colors. Following the standard hue specifications is important for sensation. Regarding illuminance, it is affected by the light falling on the pictogram and both intensity of light and reflection of the surface need to be taken into account in

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selecting the fixed position of the pictogram. Dark adaptation [15] should also be taken into account for work-posts including dark areas.

The effect of the background is important for distinction, as lighting contrast can make the same shading look more or less dark [16]. Adjustment in the background contrast is easier when only one category of pictograms is included, but more complex when various kinds of pictograms (of different color) are involved. A common neutral (e.g. white) background might be more effective in most such cases.

Finally, directed sensation, as described in Paragraph 2 may apply in certain cases, where gaze is consciously directed to seek for a sign. This can be initiated in case of motivation (e.g. after seeing a related sign) and will be discussed in later stages, where this motivation might apply.

3.2. Perception

Perception will be analyzed into two sub-stages: detection, where stimuli are automatically selected for further processing and comprehension, where detected stimuli are accurately translated into information.

3.2.1. Detection

A huge number of visual stimuli appear in human visual area every second. Of course, not everything that is seen is also detected. The majority of stimuli are crowded out by other (perceived as) more important information and rejected before finding their way to the working memory. This rapid massive purging takes place in the stage of detection based on unavoidably less-than-accurate criteria, either of stimuli characteristics (bottom-up) or internal prejudice (top-down).

According to Wickens and Carswell [11] there are four modes of attention:

- Selective attention, where there is free choice of information to be processed.
- Focused attention, where effort is on keeping attention to a certain process without being distracted (e.g. driving).
- Divided attention, where more than one attributes or elements need to be processed simultaneously (multitasking).
- Visual search, a combination of all other modes, where a certain object is sought (e.g. looking for someone in the crowd).

Although the tasks performed by a worker may fall in either mode of attention, the task of safety sign processing falls in selective attention, as communication of the sign is not aimed to compete other tasks for cognitive resources neither it is expected that a safety sign will be sought. Attention is not readily directed to fixed safety signs and they have to be implicitly processed in many cases [4]; but they are present for a long time waiting for a suitable moment to attract attention.

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In this attention mode, there are four major factors that attract visual attention to a certain constant stimulus, two of them mostly related to bottom-up process [11]: Salient features and effort required to attend.

Salient features are related to basic features of the stimulus, like size, color, etc. The effect of color (angle where each color is detectable), size (the bigger, the better), brightness and lighting on sensation (Paragraph 3.1) also applies for detection. However, given the limitations of short-term memory and working memory, salience maximization cannot apply for many stimuli at the same time and, therefore, proper allocation of attentional resources is required to be pursued. Differentiation of salient features to prioritize different signs (e.g. larger size for priority signs) seems like a reasonable tool for attention allocation but it is not supported by significant relevant research (there is a risk that less salient pictograms will be ignored at all as unimportant).

Effort required to attend for fixed pictograms mainly refers to the body posture (e.g. neck position) required to bring the pictogram into the visual field. This allows for proper design, as the location in fixed signs is stable within the area described in Paragraph 3.1. Other relevant factors are the size of the sign (too small or too large) and clutter obstructing visibility. Clutter sources (like those of Paragraph 3.1) may also affect detection (a sign is visible but its stimulus is weak). Moreover, some further sources of clutter apply for this stage:

- Salient objects catching attention away from signs (close to the viewer and/or in a 1° angle – [11])
- Excessive signage that will only weaken the impact of important signs.

However, additional information should not always be considered as clutter. Although it is usually assumed that removal of all other stimuli (e.g. a white wall) would enhance the chances of the stimulus to be detected, this is not always the case. Proper consistent framing (e.g. grouped with relevant and more salient signs in a separate contour) that predisposes the recipient could enhance these chances. Such framing depends on the number and variety of signals, but in any case, a proper "enhancing" context could be applied to assist detection ([17], [11]).

Top-down approach refers to the effect of working memory on detection. In the case of visual signs, this is related to the visuospatial sketchpad (i.e. the current perception of the working space and position of items in it) and the episodic memory (situations that can be remembered or envisaged). Two factors of detection related to this top-down process are expectancy and value of information [11].

Expectancy refers to time and location of information. For fixed pictograms time and location are related (timing is where the worker is expected to be when performing a certain task). Expectancy is related to this location, which defines whether a worker was expecting to find such a pictogram at this area or whether its presence there makes sense in general. Proximity Compatibility Principle refers both to the order of signs (information for related actions should be placed together without interfering information) and to the proximity of the locus of action concerned (e.g. control of a dangerous part). Another form is format expectancy, i.e. presentation of the information in a way the recipient is used to also enhances detection likelihood. In this case, format expectancy also has to do

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with how usual and formal signaling is as a source of information or the how common the genre of pictograms is to the recipient.

Value of information refers to the initial estimate of the value of information of the pictogram before comprehending its content. There is evidence [4] indicating a higher potential for warning and prohibition signs at this early stage. Moreover, episodic buffer (fed by episodic long-term memory) can be stimulated by proper (familiar) content (e.g. similar to the real picture).

Background spaciousness (sufficient distance between signs) provides some idle time in terms of stimulus, which can be important for sensation as sensory memory can be better utilized to assist detection in a quick scan, when no further stimuli are added. Grouping of relevant signs can also be useful here, as distance between relevant signs ("parts of the same story") can be closer than between non-relevant signs.

In this stage, the C-HIP model distinguishes between two stages: attention switch and attention maintenance, indicating that stimuli that can be initially detected may be re-evaluated and either be rejected or be further processed. In a relevant study [4], different electroencephalogram data for earlier and later stage indicated lower potential of early attention for mandating signs compared to prohibition and warning signs that do not show significant differences among them. Moreover, the same study indicated that warning signs elicit a greater hazard perception than prohibition signs and even greater than mandatory signs at a later stage of processing.

Like in C-HIP model, loops exist in cognitive information processing stages. Therefore, attention caught in the detection stage could lead back to sensation (turning gaze to check again the pictogram and/or any other stimuli close to this), which is presented here with a dotted arrow in Figure 1. This is an important effect that could attract attention (at a second stage) to information relatively of low salience if an "attractor" is effectively designed and posted. This is further discussed in Paragraph 4.

3.2.2. Comprehension

Given that a sign has been detected and attracted attention, comprehension is the next stage, where information is accurately translated. The information communicated by the three examined types of signage has some important differences.

- Warning pictograms (e.g. "hot surface") are more susceptible to ambiguity and require more cognitive effort in order to lead to certain behaviors, as they do not include an assessment of the hazard (e.g. "how hot?", "sometimes, frequently or always hot?") neither the proper behavior is obvious (e.g. "just leave air flow uncluttered to cool", "do not approach sensitive devices", "do not lay cables", "do not leave flammables close", "do not touch", "do not approach", etc.) On the other hand, these pictograms can include all this (uncertain) information in one single sign.
- Mandating pictograms are much less ambiguous and cognitive resource consuming than the other two categories, at the cost of more narrow scope: the expected behavior is clear, but this is only a small part of the overall picture, as no explanations are provided (i.e. explaining why).
- Prohibition pictograms are less ambiguous and consume less cognitive resources than warning signs, but more than mandatory signs, as exclusion of a behavior (e.g. do not override the conveyor)

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does not necessarily lead to another certain behavior (e.g. “do not also crawl under the conveyor”, “do not pass items over the conveyor”, etc.) and positive guidance is generally preferable compared to negative guidance (prohibition). On the other hand, there is sufficient evidence supporting that negative utterances, like prohibition, get more attention, arouse more emotions, have more influence on recipient behavior, and are stored better and longer in memory ([18], [19], [20], [21], [22]). Moreover, they are more associated with danger [23].

Taking also into account the effect of different pictograms in detection (Paragraph 3.2.1), it is evident that these three different kinds of signs can play a different role in affecting people’s behavior [4] in different ways an in different stages of information processing. According to Laughery and Wogalter [2] explicitness of the context, in terms of hazard, consequences and instructional information is important. This can usually be achieved through combined signage of different pictograms for the same behavior (“telling a story”).

Similarly to the effectiveness of expectancy for detection (how relevant the sign is to its context), there is evidence that the context (either real or in a photo), enhances comprehension of pictorials as people tend to seek for cues that match the situation presented by the pictorial [24]. Posting a sign close to the point where action must be taken or in otherwise relevant context, enhances both detection and comprehension.

Regarding the effect of the content on the comprehension of the sign, relevant studies show that more abstract representations (e.g. a drawing or silhouette instead of a photo) are more effective [25] and are perceived as more risky [7], although there are also studies [26] indicating that they are less comprehensive. In the latter study it is also indicated that simplicity, familiarity and direct visualization had a positive effect in comprehension.

An abstract representation can set the focus on the target behavior with less clutter, but it has to be familiar to the recipients of the information. Some further factors that could affect this familiarity are [11]:

- Semantic associations. Signs already create such associations (red for prohibition, yellow for risk and blue for obligation). These standardized associations may come in contrast with other associations, either contradictory (red is frequently a color for risk – e.g. fire sirens) or irrelevant (e.g. red is associated with hot, which could be confusing, e.g. for risks related to high temperature). Other studies [27] show that some colors have different meanings and acceptance in different cultures. Moreover, various situation-specific associations may also apply.
- Domain knowledge of the recipient (level of knowledge of those to whom information is attended to) should obviously be taken into account about which information is required and in which form.

Abstract genres also have the advantage that they can less likely be linked to certain characteristics of the depicted archetype (gender, role, race, etc.) that may affect comprehension.

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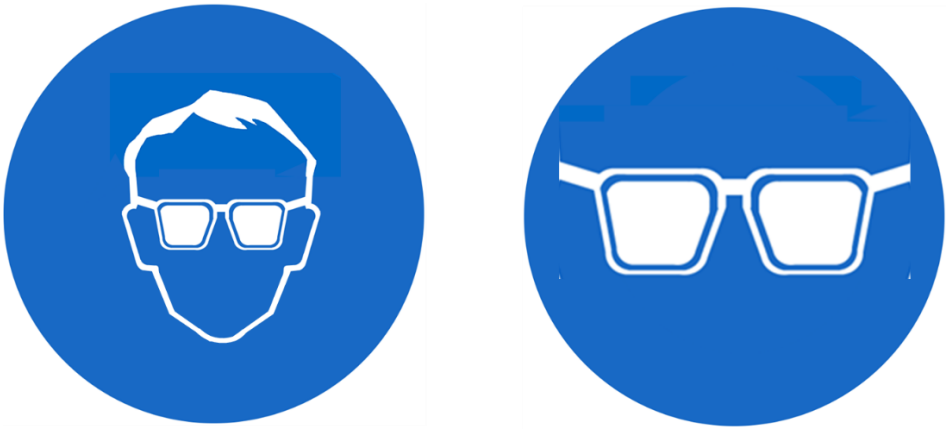

Figure 2. Two signs for mandatory use of eye protection. The left pictogram implies a clean-cut, young, white male. The right one is neutral.

Culture is another factor that has been identified to affect comprehension ([25], [28], [29], [30]) but not always [26], although other features like gender, educational background and work nature do not appear to have a significant effect [31] in comprehension of safety signs.

Comprehension is described in C-HIP as "comprehension memory", which emphasizes on the transition of the stimulus after this stage to the long-term memory as a complete information that can be accurately retracted in working memory when required. This is also linked to the vividness of information [32], which is determined by similar factors, like:

- Emotional content, related to sign's content and episodic memory.
- Concreteness and imagability, related to familiarity of the content.
- Temporal and spatial proximity, as already indicated.

This is not a completion of the role of the sign, as it should also affect the assessment and response (rather than being consciously ignored). In C-HIP, this includes the stages of attitudes-beliefs and motivation that are included in next Paragraph.

3.3. Decision and response selection

This next stage has to do with conscious decision making of the recipient against the information that has already been sensed, detected and understood. Information that has been comprehended is not necessarily positively evaluated. The two substages of assessment and decision-making are examined together in this Paragraph due to their close interaction, although they are cognitively distinct.

In literature of Behavioral Economics or Risk Perception, there are several approaches and models describing how people make decisions in an uncertain situation. Each of these models is usually appropriate for some certain situations, with specific conditions and characteristics.

For example, Risk Homeostasis Theory [33] is applicable for situations where individuals possess control over their risk exposure and have a compensating benefit for this exposure. Prospect Theory [34] applies to situations where risk can either be framed as opportunity or threat. Value expectancy

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models (like The Theory of Reasoned Action [35], Theory of Planned Behaviour [36], Health Belief Model [37], Protection Motivation Theory [38]) are focused on individual decision making based on personal attitudes and intent. Safety Culture and sociocultural approaches in general are applicable in situations of collective attitudes or decision making. These features are either not present or not dominant in the general case of decision making against a risk that is described by a sign.

Mental Models approach appears to be more relevant in the examined case of fixed signs, as it takes on a wider view of each individual in the work environment, being affected by the social context [39], but the decision for protection remains with the individual. A mental model is an abstract, intuitive and subjective representation of the system, affected by individual and group factors. It is holistic, as it outlines an understanding of the order (visual semantics) and the function (episodic memory) of the system and hence it allows for making decisions fast and easy. Mental models tend to be very similar among small and homogenous groups (e.g. workers, electricians, foremen, managers, etc.) of the system.

This approach allows to list a number of heuristics and biases that may apply in each case and can be taken into account in selecting the proper pictograms for each situation. Although each type of bias or heuristic could have a different effect in different situations, some generic clues can apply for some categories of them.

One category is biases that have to do with a perception of differentiation (compared to other individuals) that the individual develops against the risk. This category includes Optimism bias [40], where people tend to feel that for some reason the risk is lower for them, the Dunning-Kruger effect [41], which is the tendency of people to overstate own capabilities and skills, Self-defensive attribution [42], according to which people tend to explain risk in a way that minimizes their personal responsibility and “Just World Belief Theory” [43] according to which people tend to attribute exposure to risk to certain characteristics of the exposed person, assuming themselves safe as they do not share these characteristics.

Such biases could either be a result of collective perception or distortion of episodic memory. According to Chan and Ng [26] significant factors here are relevant experience (work or location) and relevant injury experience. Pictograms that can be somehow related to specific characteristics (e.g. gender, race, role, etc.) could initiate or enhance such biases. Although episodic memory of all individuals can be predicted (it depends on personal experiences and beliefs), collective experiences (e.g. recent accidents) and perceptions in the workplace should be taken into account in designing the proper signs.

Another group of biases has to do with workplace organizational inertia. An example of such biases is Status quo bias [44], where people tend to prefer existing situations over transitioning to new ones, and Confirmation bias [45], where individuals prefer evidence that supports their existing opinions while neglecting evidence that contradicts them.

These biases constrain the adoption of a sign that opposes to existing views and habits. This constraint underlines the limitations of safety signage as a management tool, and shows the necessity for training and consultation, in order to change poor existing practices. On the other hand, it shows

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the importance of effective design of pictograms in order to avoid at least unnecessary conflicts or finding ways to challenge existing practices sideways rather than head-on (e.g. emphasizing on warning signs rather than prohibition or mandating signs, or supporting the latter with explanatory warning signs, or a "story-telling" combination). Although emotions are a strong tool to enhance attention, it should be used with cautiousness in such cases.

Another category is biases that have to do with temporality and duration of exposure to risk. They include Accumulation bias, where each exposure to risk is taken as independent and separate without seeing the cumulative exposure for a long time (e.g. car crash probability 0.00001 per each trip rather than 0.33 for 50 years of driving [46]) , Present bias [47], which is the underestimation of future risks and Hindsight bias [48], where people focus on recent incidents underestimated the risk of incidents that have not happened recently. This applies more to risks of long latency (e.g. health risks) or low probability. Based on practices from Public Health campaigns, emotions could be a helpful tool to enhance motivation.

Another important bias related to visual semantics is Cerebral Contiguity, which is the tendency to connect two factors only because they are temporarily or spatially close. This is in accordance to the Proximity Compatibility Principle (comprehension stage) and could be either helpful (when signs are in spatial proximity to the point of action) or harmful (in the opposite case).

Heuristics are "mental shortcuts" for certain issues (unlike the holistic mental models) that are not necessarily misleading (like biases) but could affect comprehension either positively or negatively. They are not undesirable, as they can help comprehension and assessment, reducing the required time and attentional resources. Therefore, it is important to examine some of them that could have an important effect on signage like:

- Representativeness heuristic [49], which is the tendency to assign facts or situations (signs as well) in certain categories (e.g. typical, important, etc.) only on the basis that they look representative of this category. Categorization of signs in less effective categories (e.g. "typical only" or "not for me") should obviously be avoided. Signs of high importance should be designed and posted in a way that is differentiated from other low priority signs. On the contrary, common features of some (less critical) signs could help comprehension easier and faster, using representativeness heuristic.
- Affect heuristic [50]: which is the effect of emotions that are created by the situation on individual's assessment of risks. This is also related to the content of the pictogram and the emotions (e.g. dread, burden, etc.) that are caused by them, as well as with conflict with existing habits and beliefs. Content emotions can be linked to objective clues (e.g. presenting an injury) or objects related to incidents that have already occurred in the workplace, both of them addressed to the episodic memory. Igniting such emotions can be helpful to attract attention but it has to be used with cautiousness, so that attention is accordingly guided to the most important signs, or signs referring to cases with lower motivation potential and unnecessary conflicts are avoided.
- Availability heuristic [49], which is the tendency to perceive things that are easier to envisage (or else link to episodic memory) as more likely. Pictograms that reflect a content familiar and adapted to the situation (e.g. switches or PPE that look like those referred to) could be more effective in this respect. On the other hand, pictograms referring to risks or situations of low availability should present both consequences and target-behaviors (e.g. in a group).

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The role of safety signage is not completed, neither in the stage of decision making. Formulation of attitudes and beliefs and motivation do not necessarily lead to the expected behavior, since factors in the stage of action (failure in internal and external resources) can lead to different action from the one planned. In C-HIP this is the separate stage of behavior, which is presented in next Paragraph.

3.4. Response execution

Response execution includes the availability of sufficient resources for execution (capacity) and the effective application of the sufficient resources to achieve proper response (reliability).

3.4.1. Reliability

Although signage is mainly focused on the earlier stages of cognitive effort, it can also be helpful in dealing with some features of action, such as human reliability (or else human error) if their main causing factors or patterns are taken into account. The most common taxonomy of types of errors comes from Reason [51] and includes error types in three categories of action:

- Skill based, where simple tasks are executed without significant cognitive requirements.
- Rule-based, where selection of the proper predefined rule per each situation is required.
- Knowledge-based, where new solutions must be devised (e.g for new situations).

There is a large number of types of errors in these three categories. Knowledge-based errors include problems with comprehension and decision making that have already been examined in Paragraph 3.2.2 and 3.3. Of Skill-based and Rule-based errors, most types apply to certain situations and conditions and not in a generic level, however, there are some exceptions with a more general application field that is useful to examine further.

Such errors at skill-based level that can be assisted by signage have mostly to do with location and temporality, including Double capture slips, Perceptual confusions. Omissions-Repetitions-Reversals, Interference errors and Reduced intentionality.

Double-capture slips, are cases where a stage or a process of a task changes (the others remain the same) and errors are associated with returning to old habits. Perceptual confusions are cases where people may accept wrong things that look alike, do a similar job, or are in the right location.

Although the nature and causes of these types of error are not similar, in both cases signage should be focused on certain tasks or objects susceptible to such errors (e.g. new or similar to others) that must be identified, and signage is meaningful not only in close spatial proximity but also in spatial compatibility, i.e. if the things or tasks susceptible for confusion are spatially in different points, signage has to be adapted to this (e.g. a pictogram in the point of the wrong thing or task).

Two principles that could be important in such cases are:

- Compatibility: location of signs compatible to location of tasks or risks (e.g. pictogram in left side for left side stimulus)

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- Response confusability. When responses are similar in different situations, using signage (e.g. with a profound difference) to assist discretion.

Reduced intentionality includes cases where intention to execute an action is overlaid by other demands, particularly when there is delay between formulation of intent and execution. Although it is usually expected that time has a positive effect on reliability, sometimes long delays could have reverse effect due to decreasing working memory [11]. Signage in these cases could act as a reminder utilizing spatial proximity. Re-organization through "story-telling" signage could also be helpful.

At the rule-based level there are many types of errors related to choosing a general or existing rule that does not apply in the certain case. These errors include First exceptions (a confounding "strong-but-now-wrong" practical rule), Signs, countersigns and non-signs (failure to see that a general rule is inapplicable in the certain case and rejection of countersigns), Rule strength (selection of a 'strong' rule without checking if it totally matches in the particular situation), General rules (preference to higher level rules) and Action deficiencies (adopting a wrong rule and following it strictly).

All these situations have the common goal to underline the necessity to follow an "exceptional" rule instead of another certain rule that is perceived as the right one. Combined signage (e.g. indication of which rule is used when) in "story-telling" groups with more than one pictograms in a common frame (per rule) could also be useful in this case.

3.4.2. Capacity

Capacity is the second ingredient of response execution and it includes internal and external resources required for performing the task. Although capacity cannot be affected by signage, it is essential to be considered in planning signage, as the latter can be negatively affected by poor capacity. For example, signage for using Personal Protective Equipment (PPE) when internal (training on proper use) and external (existence of proper PPE) resources are insufficient, could have a negative effect on reliability of signage in general.

4. SYNTHESIS

The aim of this paper is to present a practical guide for fixed safety signs based on cues from existing research, presented in previous Paragraphs. This guide actually includes the first three preparatory stages of the C-HIP model. Like in C-HIP, there are loops between each of these stages as each one affects the other and the final decisions are a result of a spiral process.

In terms of signage application, there are three interacting stages: selection of target-behaviors, design of pictograms and location.

4.1. Selection of target-behaviors

Signs aim to promote or discourage certain behaviors. Due to spatial and cognitive limitations, not all targeted behaviors can be signed; selection of the most proper ones should apply.

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The selection should be based on a documented evaluation and prioritization in terms of contribution to safety. Evaluation should combine the priority (magnitude) of the risks related to each target-behavior, with an estimate of the impact I(r) of the target-behavior in reduction of each of these risks. Actually, the evaluation of each target-behavior is the sum of the products of risk assessments R(ri) (a combination of likelihood and severity) times impact I(ri) for all risks related to this behavior ($E=\Sigma R(ri)\bullet I(ri)$).

This evaluation will provide a prioritization of target-behaviors for the certain area (work-post). Of course, not all target-behaviors can be effectively put into a fixed sign. Therefore, the assessment has to be continued qualitatively for each situation, in order to exclude target-behaviors that cannot effectively be presented with a pictogram and will be pursued by other ways (e.g. training, automation, etc.)

Particular situations that were identified in Paragraphs 3.3 and 3.4 and where signage is exceptionally important should also be taken into account in qualitative evaluation. Such situations include new or rare situations, measures in conflict with existing behaviors, new or rare rules (criteria) for action, spatial incompatibility, response confusability and long delays or latency of consequences.

4.2. Design of pictograms

The next stage is the design of the pictogram. This includes a number of features, like color/type, size and content:

Colors and hues are standardized per type of pictogram (RAL codes should be always used), but the choice of the type of pictogram is a key issue. As already mentioned in Paragraph 2, a prohibition or warning sign is more likely to attract attention, while mandating signs could convey more direct information. However, [2] information about hazard, consequences and instructions (probably in different signs) is important for effectiveness. This may be in conflict with brevity, which is another important factor for attraction of attention. Therefore, the choice has to do with a trade-off between priority and content within space limitations.

However, the correct choice is not simple as there are contradictory features in each type and should take into account the following criteria:

- Whether the behavior-related information can be codified in different kinds of signs (or any kind of sign). For example, this is the case for avoiding contact with a hot surface (obligation to stay away, warning for hot surface or prohibition to contact) but not the case in “keep silent”.
- Whether few mandating or prohibition pictograms can describe all aspects of the intended behavior (e.g. “keep silent”) or not (e.g. “hot surface”), otherwise warning pictograms are more effective as they can contain more (but less certain) information.
- Whether risks or intended behavior is obvious otherwise mandating pictograms are more effective to communicate the necessary behavior.
- Whether extra attention is required, where prohibition pictograms are the most effective and mandating pictograms the least effective.

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For size, generally, the bigger, the better for attracting attention (always within space availability limitations and critical size, depending on the distance from the viewer). Differentiation of size according to the priority of the sign is not advisable.

Regarding the content, abstract genres are more effective and have to be carefully designed in order to exclude any intuitive connection with specific characteristics of workers. Although abstract in nature, content has to be specific to the situation and look familiar (e.g. if a specific switch has to be kept closed, the switch in the sign must look like the specific one).

Figure 3. Abstract signs with different familiarity to the real situation.

Familiarity also refers to the recipients. The whole format of the pictograms must be adapted to local characteristics of the recipients (workers) in terms of local semantic associations, domain knowledge and culture, so that it looks familiar and relevant to the workers of the certain workplace.

Affect. Genres that ignite emotions (e.g. from incidents that have occurred or can be easily envisaged) are a tool for enhancement of attention attraction potential that has to be carefully used in order to prioritize the correct pictograms. It can be particularly useful in exceptional cases of new or rare risks or rules, where no previous experience exists, or temporality biases exist. On the contrary, it should be used carefully when they are in conflict with existing beliefs and behaviors, where warning signs and “story-telling” pictogram groups are more preferable solutions.

4.3. Location

For fixed pictograms, available space, which usually coincides with the area covered by a work-post, or more specifically, the available surface near the usual area of presence of a worker, defines how many signs will be posted.

Therefore, it is essential to define the available space for signage. This includes the projection of the usual position (height of eyes) of the worker on the opposite surface (wall or free equipment surface) in two levels: an angle only 20-30° where all kinds of pictograms will be spontaneously visible and an angle of 40-60° where only blue mandatory and yellow warning pictograms will be spontaneously visible. In case of grouped pictograms the area can be extended beyond these limits, as given that attention is initially attracted to the first pictogram, conscious sensation (turning gaze) could apply to the rest of the framed pictograms.

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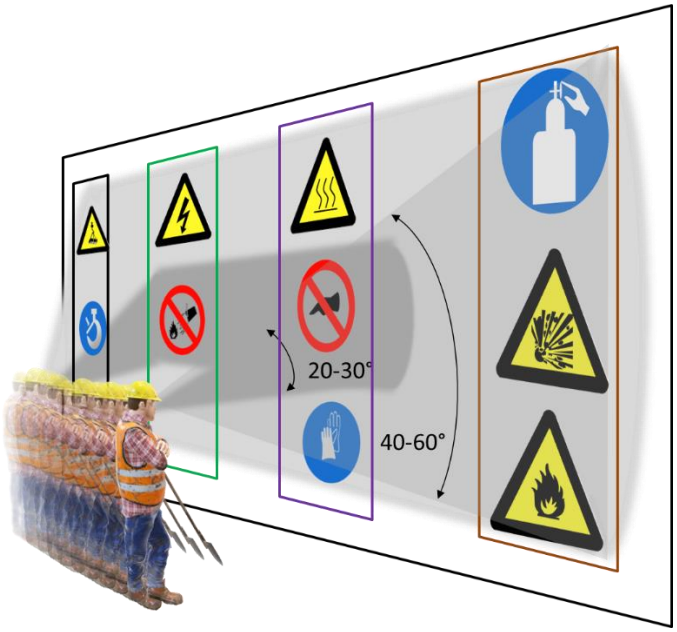

Figure 4. Location of pictograms in relevant visibility areas and groups.

Grouping and framing of pictograms could be a very useful practice for a number of reasons, particularly when combined signage is applied for the same behavior. It refers to gathering pictograms that refer to a certain risk, task, situation, etc. together and distinguishing them from other signs. First, this creates a coherent context that helps faster and easier comprehension of signs. There is evidence [17] that an "enhancing" surrounding environment has beneficial effects in behavioral compliance, even without greater salience.

Second, it allows for distinguishing different situations where different target-behaviors may apply. Framing could be applied through backgrounds of different colors but due to contrast issues or semantic associations (e.g. a red background could imply prohibition or fire), a white background in a contour is proposed. To avoid confusing different situations (with different demands), contour could have different colors. This could be particularly useful in cases of response confusability (similar responses to different situations).

Spatial proximity is another important factor. Pictograms are more visible and comprehensive when posted close to the point of action. Of course, this is not always possible when different risks, tasks or situations take place at the same point. Framing and application of the compatibility principle (choosing the most relevant side, height, contour color, etc.) can be useful at this respect. On the other hand, proximity of signage to irrelevant points should be avoided, particularly critical ones, as erroneous connections based on spatial proximity only could be developed (cerebral contiguity).

Background spaciousness is important within the physical limitations of the situation. Apart from improving visibility, detection could be improved by better utilization of sensory memory. The available surface according to these four factors and the vertical distance from the usual viewer's position) are those that define how many (hence which) and how large fixed signs can be posted.

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Clutter is a term commonly used in scientific and grey literature about anything that could constrain visibility or add unnecessary information that will obstruct perception or comprehension. Some such clutter sources (identified in Paragraphs 3.1 and 3.2) can be described as:

- Improper surface for posting signs.
- Objects obstructing visibility or catching attention away from signs.
- Dirty or worn-out signs.
- Excessive signage.

5. CONCLUSION

Although safety signs are an important and very common measure for safety in workplaces, they are usually applied in workplaces without a certain methodology and guidelines based on a human factors approach. Existing research has studied only some of the many aspects, situations and stages of human information processes related to safety signs.

This paper aims to provide a certain practical guide for safety signage based on findings of existing research, as well as human factors analysis in aspects, situations and stages where no sufficient research evidence exists. Such a practical guide is feasible only in a small group of safety signs with common features. These signs in this study are fixed safety pictograms (excluding fire and emergency as well as signs rarely encountered).

The findings of existing research and analysis were gathered in three basic stages of application of safety signage: selection of target-behaviors, design of pictograms and location with certain guidelines. Although several aspects remain to be researched, this guide could help a more structured and effective application of the examined category of safety signs in workplaces.

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