Color blindness and modern board games

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Abstract

Board game industry is experiencing a strong renewed interest. In the last few years, about 4000 new board games have been designed and distributed each year. Board game players gender balance is reaching the equality, but nowadays the male component is a slight majority. This means that (at least) around 10% of board game players are color deficient. How does the board game industry deal with this? Recently, a raising of awareness in the board game design has started but so far there is a gap compared with (e.g.) the computer game industry. This paper presents some issues about the use of color in the boardgame design and same data about actual situation of boardgame publishing.

The daltonic boardgamer

This paper aims at presenting the problems of considering color deficiencies in the design and development phases of modern board games. Some issues will be presented and discussed to show how the lack of attention of this problem in both phases can lead to board games not playable by color vision deficient gamers, and in many cases hard to play also for normal color vision observers. The paper will present a different approach on scientific research about color deficiency in context and will discuss possible approaches to design more inclusive boardgames.

A wider approach on color deficiency

The common idea about human color vision process is like what happens in a color camera: there is a color sensor at each "point" and it generates the color final sensation at that point (maybe with some demosaicing). In reality, color vision is a much more complex phenomenon which involves not only the signal transduction in the retina, but also an important stage of spatial signal processing. This second stage is fundamental and is where human vision robustness takes place with its important adjusting mechanisms, like e.g. color constancy [1]. Another important task of spatial processing in vision is the recovering of signal dynamic loss on the retina due to eye-bulb glare [2]. In fact, what arrives on the retina has a strong decrement of contrast and sharpness due to the scattering of light in crossing eye lens and body [2, 3, 4]. This loss can produce a reduction of contrast up to 3 or more orders of magnitude, like measured in an experiment [4] where we have found a reduction from about 250.000:1 at the cornea to about 150:1 at the retina.

This spatial part of vision is known and agreed since the 50's [5-15], but often not considered in many research topics about color. Color deficiency is one of these.

A Color Deficient Observer (CDO) has a type of anomaly in the response of one type of cone, but shares the same structure of the vision system, including the spatial processing part. How spatial visual processing affects the final color sensation for a CDO ? The behavior of spatial processing for color deficient observers is a quite recent field of study [16-20], but we find it particularly interesting.

In any case, how are CDOs considered in the fast growing market of boardgames ?

The boardgame industry

Boardgame industry is rapidly growing since the end of the 90s. In Fig. 1 it is shown this trend, where is clearly visible the change of slant around 1997-98 and the assessment bump of 2020 due to Covid-19, followed by the Ukraine war. These two facts have caused the cancelation of fairs and conventions and consequently the stand-by of many boardgames under development. Moreover, production and shipping problems from China and other productive countries have also to be considered, together with the lack of raw materials.
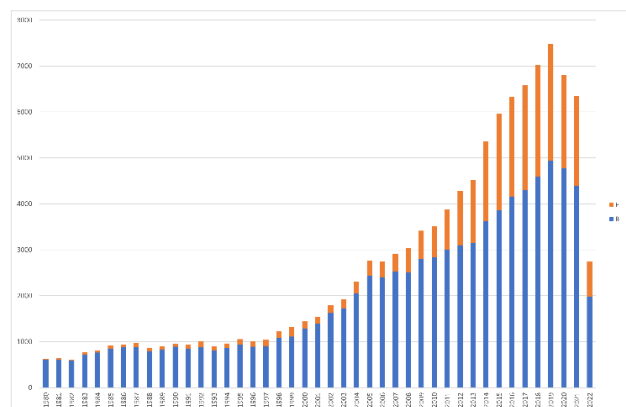

Figure 1. Number of new boardgames (blue) and expansions (orange) per year from 1980 to 2022 (March). source: Board Game Geek [21]

Regardless all the above problems, in October 2020, Growth Market Report estimates the boardgame market growth around more than 28B$ in 2027 [22]. Considering the about 5000 different boardgames produced in 2019, the major part is produced in the range of 1000-5000 copies, a limited amount ranges from 50,000 to 100,000 and only a few arrive to a million copies sold per year [23]. Here find more details about boardgame player community characteristics [24].

What is the impact of CDOs on boardgame industry ? Considering that nowadays 69% of board gamers is male [24] and around 8-9% of them is CDO, CDO inclusivity could potentially increase sells by about 7%. However, the boardgame market fragmentation can change this level of impact. The strategies of CDO inclusion can differ widely among publishers. In some cases, for a small publisher, producing small amounts of games per title, sell increment could not compensate increment of costs for CDO inclusion work.

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Color design and use in boardgames

Boardgames use color very often, e.g. to increase visibility and discrimination among resources (see Fig. 1) and to convey meaning on cards and boards.

Figure 1. Colored meeples, a classic boardgame resource

There are mainly two classic approaches to keep discrimination considering potential CDO players.

The first approach is the use of suitable color palette, especially devised for CDOs, like the ones reported in Fig. 2.
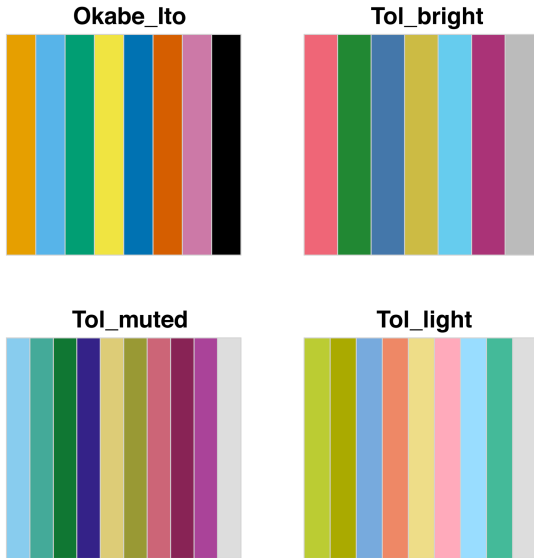

Figure 2. Examples of CDOs color palette. (Source: https://thenode.biologists.com/data-visualization-with-flying-colors/research/)

A suitable color palette is surely a useful approach to maximize discriminability among board-gamers, not only CDOs, but the "price" to pay can be manyfold.

Color CDOs palette can be more or less effective according to the number of colors they need to code, the more the color the more the chance to have color couples not distinguishable for some type of CDOs. There are many different types of CDOs and the bigger is the palette, the more there is chance to be non discriminative for every possible CDO type. The four palettes in Fig. 2 have been tested in our lab with CDOs and we found two couples not distinguishable for a deuteranope. We do not report these cases in detail since it is out of the scope of the paper. Moreover, there are cases for which the color palette has been found unattractive by normal gamers since unusual or not enough saturated.

It should also be considered the effect of the context. Edges and complex visual arrangements have proven to change the response of CDOs [19, 20]. Furthermore, the light condition where board game is played could increase the problem for both CDOs and non-CDOs players, making the proper palette not so easy to choose.

Another problem is color reproduction across different media, for which a printed board can be different from a wooden or plastic resource intended to have the same color. Gamut problem can be also the result of the design process like the example of Fig. 3 in which the same card has the same resource (shape-reinforced) printed in two different greens and in two different ways (2D and 3D).
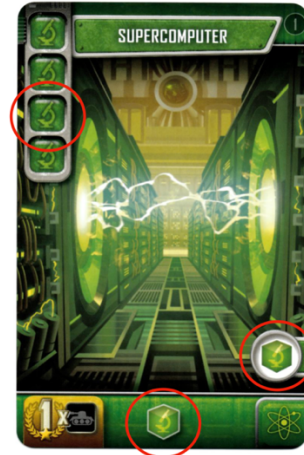

Figure 3. Different color and visualization of shape-reinforced color resources on a card.

The second approach is to add a shape to colors, so to reinforce the meaning and to prevent potential CDO mismatch (Fig. 3 and 4). This is surely a positive and effective approach. In this case a possible problem is the increment of the production cost if the shape differentiation regards physical resources, like e.g. Fig. 4.

Figure 4. Examples of shape-reinforced color meeples. (source https://www.herotime1.com/)

This solution is used in traditional card games such as modern ones (Fig. 5) but not all the games use this approach. The typical problem is to find a clear symbol and give the good weight in the graphics layout to allow to all CDOs to easily distinguish it during a game.

In Fig. 5 are visible different approaches in reinforcing color with shapes. In Fig. 5-top it is used the ColorADD system

(https://www.coloradd.net/en/). This method aims at preserving color mixing properties (subtractive) but suffers the problem of rotational non-invariance. For these reasons in the jolly (third card from the left) symbols are underlined. In Fig. 5-middle the unique symbols used to identify colors do not follow any rule of additivity or other. The difficulty in this case is that many different designers can result in as many different "alphabets". In this example shapes are reported quite small on the card, resulting in potential readability problem. In Fig. 5-bottom symbols are designed considering the visual contest, searching visual harmony, this implies a graphic study during development phase with relative increment of production costs.

Figure 5. Examples of symbol-reinforced by top) using ColorADD; middle) using ColorBlind Friendly protocol. bottom) using a custom Symbol-reinforced.

The first Edition of Monopoly has no pawn, and the rules ask players to use small common objects as token. Starting from 1936 Parker Brothers include a set of small tokens in order to increase attractiveness of the game to consumer. At the beginning these tokens were not using colour to distinguish (see Fig. 6), later colour has been used but they always kept the shape as mean to distinguish among players [25]. During the years the importance of the monopoly token increase and becomes an important selling point. These tokens make monopoly a CDOs ready game.

Figure 6. The Deluxe set of Monopoly tokens in 1936, These tokens are CDO-friendly [25].

A further source of problem can be the type of material with which resources are made. A particularly difficult case is the use of transparent or semi-transparent resources like e.g. the dices in Fig. 7. The blue and the violet dices are a "classic nightmare" for CDOs, but in general translucency makes the color more difficult to differentiate also for normal observers.

Figure 7. Examples transparent dices.

Boardgame industry and color deficiency

Color plays very often a major role in board game design and mechanics; this means that considering CDOs is a mandatory point to address in the design phase to make an accessible boardgames.

We have tried to better focus the industry interest about research on this topic. To have more details about how CDOs are considered in the boardgame industry we have distributed a short survey to a small group of 20 Italian game publishers. Here we report their main answers.

The first question is about their knowledge on the impact of color deficiencies in the overall population. Answers are reported in Fig. 8, the major part (63.6%) knows that about 9% of the male

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population is affected by color deficiencies. This percentage should make the topic of interest for game publishers.
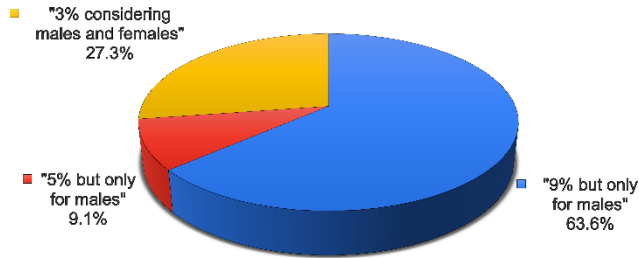
What is the percentage of CDOs in the population?

Figure 8. Survey question about percentage of CDOs among population.

The survey continues asking at which stage they consider CDOs in the development of their boardgames and what they have done so far. As visible from Fig. 9, more than 60% of the game publishers have already developed boardgames considering potential CDOs players or is on the way to consider it (9%).

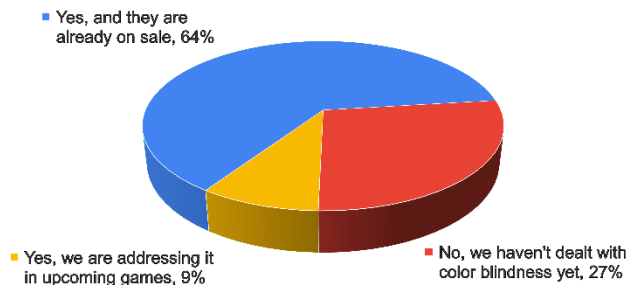## BoardGame Publisher that provide inclusiveness for CDOs players

Figure 9. Over the 63% of interviewed has at least one game published with inclusiveness for CDOs, the 9% introduce this approach in the next two years.

Then, we asked publisher that considered CDOs at which stage of the game development they start to do it. In Fig. 10 answers are reported. 13% started to consider it from the very beginning of the boardgame development, 87% started it with graphic design.
Next question regards the strategies put into play for making CDOs inclusive boardgames. The two main ones presented above (shape reinforced use of color and suitable color palette) appears in the first positions of Fig. 11, together with data about testing. Associating symbols and shapes to color is the most chosen solution, more than 85%. About the 37% of the cases choose a palette for CDOs. This reflects a market trend among non-CDOs players who appreciate the presence of particular material in games; but also, the difficulty in finding a palette that is perceived as attractive.

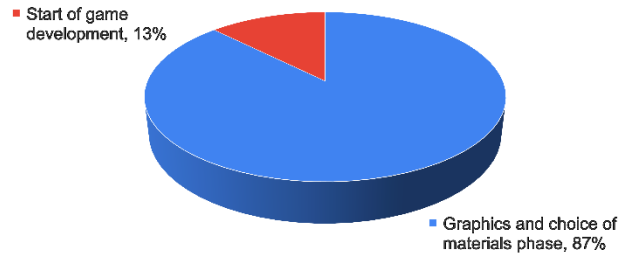## Stage of boardgame development when publisher starts to working on the inclusiveness for CDOs players

Figure 10. The 12.5% of publisher start to consider inclusiveness for CDOs when a new project is started. The others wait for the graphics development phase.

In the 50% of the cases the game has been tested with CDOs. This is a particularly important step, since the great major part of CDO simulators available consider only the retinal stage and thus can fail in predicting the effect of context.
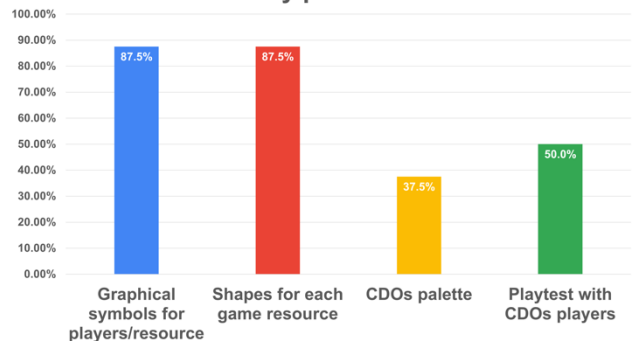
Type of CDOs Inclusiveness used by publishers

Figure 11. Shows the choices made by publishers surveyed to support CDOs while playing games.

Finally, we asked about possible services to offer to game publishers in order to increase CDOs inclusiveness in their production (Fig. 12). Answers regard all the production pipeline. The 65% of publisher who have already published games for CDOs may be interested int a graphic review service. Less than 40% are interested in playtest with CDOs player, and the 25% of them could be interested in staff training and checklist for CDOs design.
Game publishers that have not yet developed boardgame for CDOs are strongly interested in playtest with CDOs and in a checklist to assess inclusivity practices. Interest in a checklist hides the will to simplify the work for inclusiveness design, that remain in any case a complex work that surely can be controlled by a checklist, but that, in cany case, needs experience and testing with CDOs.

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Publisher interest in CDOs inclusiveness game development services

■ Publisher that has "JUST" make games with CDOs Inclusiveness
■ Publisher that has "NOT YET" make games with CDOs Inclusiveness
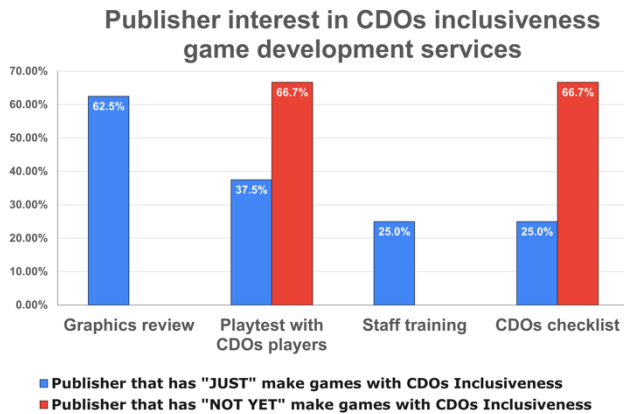
Figure 12. In Blue the answer provided by publishers who have already products games for CDO. In Red form publisher that has not produced games for CDOs.

Conclusions

Boardgame industry has registered a strong more than linear increment from the end of the 90s, until the spread of covid-19. After the actual resizing the forecast for the future are very positive and more inclusive games for CDOs can lead to a 7-10% further increment.

In this paper we present some aspects about the use of color in boardgame design trying to be inclusive for CDOs. In the second part we report the result of a survey involving 20 Italian boardgame publishers, regarding they awareness of CDOs characteristics, their strategies to cope with them and their need for the future.

Several topics remain open for future research, like e.g.: a better understanding of the spatial aspects of color deficiencies; the efficacy of color palette for CDOs in context; an agreed "alphabet" of symbols to attach to colors; the definition of a checklist for boardgame CDO inclusivity assessment; the effect of spectrum and low levels of illumination (typical in several gaming environments) on color appearance for CDOs and non CDOs.

More basic and applied research on boardgame CDO inclusiveness is needed. A shared approach could lower the cost of inclusiveness and make it an important boardgame characteristics required by future customers.

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Alessandro Rizzi is Full Professor at the Computer Science Department, University of Milano. He is researching since 1990 in digital imaging with a particular interest on color, visualization, photography, HDR. He is Topical Editor of the Journal of Optical Society of America A, Associate Editor of Journal of Electronic Imaging. He has been Secretary of CIE Division 8, IS&T Fellow and Vice President. In 2015 he received the Davies medal from the Royal Photographic Society.

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