Following the Yellow Brick Road
How LEGO uses colour to categorise and communicate themes

Tk Cram

1. Introduction

LEGO, produced by The LEGO Group, is a line of construction toys primarily comprising of interlocking plastic components (parts). These parts range from the ubiquitous bricks and figures through to gears and axles, all in a variety of colours. Parts are collected and sold as sets, which themselves are grouped into themes. It is these themes that this paper examines. Specifically:

What factors may be involved in determining the colour palette of a LEGO theme.

Given the importance of colour identity in branding (Zhang et el, 2020), it is beneficial to examine what lessons can be learned from one of the largest toy manufacturers in the world (The LEGO Group, n.d.). While a variety of research has been done on the practical applications of LEGO beyond its intended scope, little research is publicly available on the LEGO parts themselves. This paper is intended help fill this gap in the research.

Rebrickable, a third party LEGO database, will serve as the primary dataset for this analysis. A count of parts will be taken for each theme, and will be sorted by colour value. This information will be used to examine the prevailing colours of each theme, why they might have been chosen, and how they compare to other LEGO themes. As several themes tie in to third party franchises, additional data will be collected from those franchises for comparison.

2. Background

In 1932, Danish Carpenter Ole Kirk Kristiansen found The LEGO Group, the term coming from "leg godt" meaning "play well". Originally selling wooden toys, in 1958 they launched the original LEGO brick. Designed on "The interlocking principle", the bricks were able to be combined in any combination and offered "unlimited building possibilities." Since then, The LEGO Group has expanded to become one of the largest toy manufacturers and named "Toy of the Century" twice." (The LEGO Group, n.d.).

The majority of academic research involving LEGO is done with it rather than about it. That is to say, LEGO is used as a tool in construction (Chen, 2021), psychology (Sayis, 2021), or medicine (Yuan-Pin et al. (2021). Little could be found about LEGO itself.

Beyond academia, articles can be found written from a fan perspective such as "Working with the LEGO Color Palette" (Thita, 2020), "The Curious Case of LEGO Colors" (Bartneck, 2016), and "Understanding the LEGO Color Palette" (Alphin, 2016) These articles examine the history of the colours as well as an overview of what colours are used, suggesting there is work to be done on the topic, but none provide a data driven analysis.

An assumption can be made that the LEGO group has an internal research team. However, as of the time of writing the company does not allow their employees to discuss matters with students.

3. Methodology

Exploratory Analysis

Lego Dataset

The data for the LEGO parts is available from the Rebrickable database. Rebrickable is a website whose primary purpose is to "show you which LEGO sets you can build from the sets and parts you already own." (Rebrickable, n.d.) It contains an extensive list of parts, sets, and other details from LEGO's catalogue (Fig. 1).
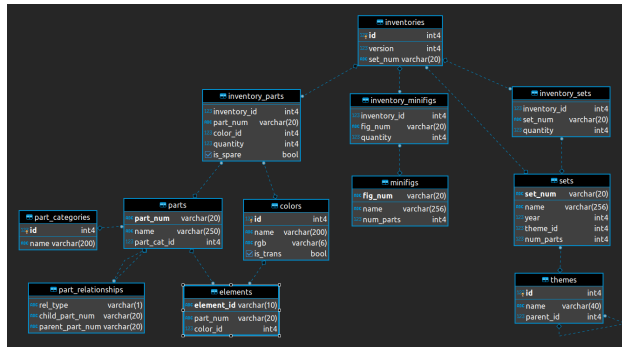

Fig. 1 - Rebrickable Schema

The most recently available snapshot of the database was downloaded on the 3rd of November, 2021. The inventory, inventory_parts, colors[1], sets, and themes tables were joined together using SQLite, producing 903,791 rows of data. A filter was added to only display sets released in the previous five years in order to mitigate the impact of historical changes in production or design philosophy. This period accounts for approximately 25% of all sets available in the database. The data was then grouped by both colour and theme (sub-themes were rolled into their parent theme), and summed for the total number of parts for each combination. The final result was 2,397 rows of data (Fig. 2).

Fig. 2 - Database Output

The outputted SQLite data was imported into Microsoft Excel and the table pivoted to create a square data frame with 68 colour rows and 61 theme columns. These were compared against what themes were listed by LEGO.com, and retired themes were filtered out. Additional filtering was applied to themes and colours with minimal entries. The result was 56 colours and 20 themes. (Fig. 3)

On average, each theme contained 34631 parts, with a minimum of 2355 (Trolls: World Tour), a maximum of 99012 (Star Wars). For colours, the average number of parts was 12509, with a minimum of 245 (Yellowish Green) and a maximum of 131124 (Black). On average, each theme used 44 different colours. 14 colours appeared at least once in every theme, with another 7 appearing in all but one. 4 colours appeared in only 9 themes, which was the lowest incidence.

Fig. 3 - Initial results sample

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[1] Hex codes for colours were created for the database. HSL data was added by the author.

In order to determine the average saturation and lightness of a theme, the data set was imported and summarised R and the results noted. The average saturation of a LEGO theme was 47%, with a range from 32% - 60%. The average lightness was 51%, with a range from 35% - 64% (Fig. 4).
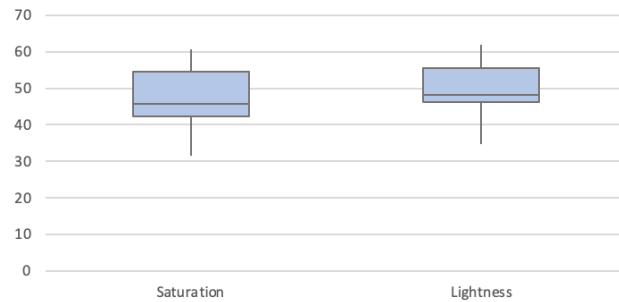

Fig. 4 average saturation and light of LEGO themes

Franchise dataset

Once the list of themes was finalised, they were separated into those developed in-house and those that cross-promoted with an external franchise. In all, 11 out of the 20 themes were labelled as a franchise theme (e.g. Star Wars, Minecraft), with the remaining 9 being being created by The LEGO Group (e.g. City, Friends).

In order to compare the franchise themes against the source material, posters were manually collected from IMDB. For consistency, promotional posters were selected where available (e.g. movies from the Marvel Cinematic Universe were selected to represent the Marvel LEGO theme). An average of 7.5 images were chosen per franchise, with a maximum of 13 (Disney Princess, Marvel) and a minimum of 3 (Minecraft, Minions).[2]

A k-means algorithm (Chauhan, 2019) was chosen to extract the colour data from the franchise images. Specifically, the Image Color Summarizer by Martin Krzywinski (2006). Each image was parsed in

turn, with a k value of 5, and the HSL data was collected.

To better match the franchise data to that of the LEGO, the decision was made to map each colour from the outputted k-means data to its closest match amongst the available LEGO colours. This was done by treating the HSL values as a 3D co-ordinate system and searching for the minimum distance. The average distance was 25, with a minimum of 0.4 and a maximum of 55.3.

Methods

In order to examine what factors may be involved in determining the colour palette of a LEGO theme, this paper took a mixed methods approach. That is to say, quantitative methods were used to summarise the data and create statistics relevant to the topic of this paper. This data was then examined through a qualitative lens to determine the final results.

To answer the research question, three datasets were extracted from the raw data: Colours, SL, and Franchise. The colours dataset originally contained the 10 colours for each theme with the highest part count, in addition to what proportion of a themes total parts those colours represented. The 10 colours was later split to be the proportion of ''Black', 'Dark Bluish Gray', 'Light Bluish Gray' and 'White' (called the monochrome group), and the listing of 5 colours and their proportion of total parts exclusive of that group.

The SL dataset contained the average saturation and lightness for each theme.

The Franchise dataset contained a binary indicator of whether a theme was connected to a franchise or not, and the franchise media's colours, saturation, and lightness statistics relative to its associated theme. The list of all colours present for each themes franchise media was collected and compared with the list of ten most frequent colours of

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[2] These numbers partially reflect the amount of source material, as well as the variety of imagery.

said theme, and the number of matches was noted.[3] Saturation and lightness averages were also taken across each franchise's media, and the difference between it and the theme's saturation and lightness levels was noted.[4] In all, this resulted in a 10x20 table.

The remainder of the analysis was done by hand. 4 categories were selected to examine more closely, gender and age demographics, if the theme was based on a franchise, and comparing the theme to the franchise itself. While demographic data isn't explicit in the dataset, the author relied on both outside reading and personal experience to select appropriate themes that fit each category. Both demographic categories, as well as in-house vs franchise were examined by averaging the figures for each theme within a category, and performing a close reading.

Comparing the theme to its associated franchise was done by plotting the proportion of colour matches and saturation/lightness difference for each theme onto visualisations (included below). Additional information was gathered about which specific colours were being matched in both the theme and the franchise media.

4. Results & Discussion

A summary of results is presented in Table. 1. What follows is a definition of terms in addition to the summary statistics.

Franchise

A Yes/No binary on whether the theme was developed to cross promote an external franchise (Y) or developed internally by LEGO (N). Y: 11; N: 9.

5 Colours

The five colours that appear most frequently in a theme, exclusive of the monochrome group. Across all 5 colour groups, 'Red' appeared in 17 themes, the highest of any colour, followed by 'Tan' (14), 'Reddish Brown' (13), 'Yellow' (11), and 'Blue' (10). 11 colours are unique to a single themes 5 colour list.

Table 1 - Summary of result

	F	5 Colours	5C%	M%	O%	CF%	S%	ΔS	L%	ΔL
Architecture	N	Tan; D. Green; S. Green; Red; T.L. Blue	31.6	50.2	18.2	n/a	33.3	n/a	64.0	n/a
Batman	Y	Red; Yellow; R. Brown; Blue; Tan	13.6	72.9	13.5	50	46.5	9.7	34.8	2.0
City	N	Red; Blue; Yellow; Tan; Orange	23.4	56.7	19.9	n/a	45.6	n/a	50.3	n/a
Classic	N	D. Red; Red; Yellow; Blue; R. Brown	30.0	26.6	43.4	n/a	53.9	n/a	55.4	n/a
Creator	N	Tan; Red; R. Brown; Blue; D. Tan	29.0	52.1	18.8	n/a	41.7	n/a	55.6	n/a
DC	Y	D. Red; Red; Flat Silver; Yellow; Blue	25.7	56.7	17.6	40	42.3	2.1	59.0	7.9
D. Princess	Y	Pearl Gold; R. Brown; Tan; B. Pink; Magenta	32.1	28.5	39.5	70	44.8	5.6	60.1	16.9
Disney	Y	Red; T.L. Blue; R. Brown; Tan; M. Azure	26.9	41.3	31.8	50	45.3	1.2	60.6	2.9
Duplo	N	Red; M. Azure; Yellow; Lime; Orange	40.3	30.1	29.6	n/a	56.0	n/a	60.7	n/a
Friends	N	Tan; M. Azure; R. Brown; D. Pink; Yellow	20.7	35.0	44.3	n/a	45.2	n/a	48.2	n/a
Harry Potter	Y	Tan; R. Brown; D. Tan; Red; Pearl Gold	40.7	45.2	14.1	60	42.6	14.2	46.9	16.0
Marvel	Y	Red; Orange; D. Blue; Blue; Tan	18.9	56.1	25.0	50	42.1	4.7	48.2	10.2
Minecraft	Y	R. Brown; Green; M. D. Flesh; Tan; Red	31.9	38.6	29.5	10	45.9	6.0	47.9	6.8
Minions	Y	Yellow; Blue; D. Red; Red; R. Brown	51.5	34.2	14.2	10	59.9	18.9	43.0	16.2
Monkie Kid	N	Red; Yellow; D. Red; D. Purple; R. Brown	22.6	51.7	25.7	n/a	45.7	n/a	50.2	n/a
Ninjago	N	Red; R. Brown; Pearl Gold; Tan; Blue	23.6	53.1	23.3	n/a	46.5	n/a	44.4	n/a
Star Wars	Y	Tan; Red; Blue; D. Tan; R. Brown	18.7	73.5	7.8	40	31.6	2.8	47.2	13.6
Super Mario	Y	Yellow; R. Brown; Red; Tan; Green	29.1	45.7	25.2	40	50.1	4.2	48.0	1.3
Technic	N	Blue; Red; Yellow; Tan; Orange	30.9	63.7	5.4	n/a	58.2	n/a	35.8	n/a
Trolls	Y	Lime; Yellow; M. Lav.; M. Azure; D. Turq.	27.4	24.6	47.9	10	54.8	16.1	54.2	12.4

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[3] This was updated with the switch to Monochrome + 5C

[4] This made no indication of whether it was higher or lower, a result added at a later date

5C%

The percentage of parts in a theme which are accounted for by its five most common colours. Average: 28.4%, Minimum 13.6% (Batman); Maximum 51.5% (Minions).

Mono%

The percentage of parts in a theme which fall into the monochrome group (Black; Dark Bluish Gray; Light Bluish Gray; White). Average: 46.8%, Minimum 24.6% (Trolls: World Tour); Maximum 73.5% (Star Wars).

Other%

The percentage of parts in the theme which fall into neither the monochrome nor 5C grouping. Average: 24.7%, Minimum 5.4% (Technic); Maximum 47.9% (Tolls: World Tour).

CF%

The Colour-Franchise percentage is a measure of the proportion of colours that were in both the ten most common colours for the LEGO theme, as well as the list of total colours for the franchise media.
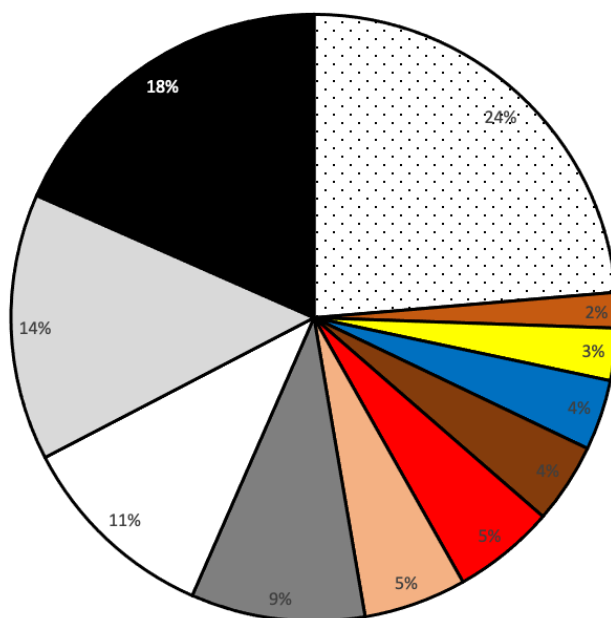

Fig. 5 - Total proportion of all LEGO colours

S%

The average saturation of the theme. Average: 46.6%, Minimum 31.6% (Star Wars); Maximum 59.9% (Minions) (Fig. 4).

ΔS

The absolute difference between the average saturation of the theme and the average saturation of the franchise media. Average: 7.8, Minimum 1.2 (Disney); Maximum 18.9 (Minions).

L%

The average lightness of the theme. Average: 50.7%, Minimum 34.8% (Batman); Maximum 64% (Architecture) (Fig. 4)

ΔL

The absolute difference between the average lightness of the theme and the average lightness of the franchise media. Average: 9.7, Minimum 1.3 (Marvel); Maximum 16.9 (Disney Princess)

Discussion

Overall

During the analysis, an observation was made that a certain subset of colours were present across all themes, which were dubbed the 'monochrome group'. This grouping consists of four colours: 'Black', 'Dark Bluish Gray', 'Light Bluish Gray' and 'White'. Combined, these four colours accounted for 52.7% of all LEGO parts in the data set (Fig. 5). Some thought went into whether to exclude this data due to its universality, but upon further inspection themes such as 'Star Wars' (73.5% monochrome) and 'Batman' (72.9 monochrome) leaned heavily on these colours for their identity. The decision was made to keep the data in, but to delineate it from the most common colours.

In addition to the monochrome group, the 5 most frequently occurring colours were selected for

Bright Pink	Black	Blue	Dark Bluish Gray	Dark Green	Dark Pink	Dark Purple	Dark Red	Dark Tan
Dark Turquoise	Flat Silver	Green	Light Bluish Gray	Lime	Medium Azure	Medium Lavender	Medium Dark Flesh	Magenta
Orange	Pearl Gold	Reddish Brown	Red	Sand Green	Trans Light Blue	Tan	White	Yellow

Fig. 6 - The monochrome group + colours amongst the 5 most common for a theme

each theme (5C). (Fig. 6). Five colours (Red; Tan; Reddish Brown; Yellow; Blue) appeared in >50% of all 5C lists, while all other colours (19 in total) appeared in <25%, and 11 appearing in only 1. 'Architecture', 'Disney', and 'Trolls: World Tour' each had two colours that appeared in no other list.

On average, the monochrome group and a theme's 5C group accounted for 75.3% of the total parts in a theme, suggesting that this was largely representative of what was available in the theme. However in four cases ('Trolls: World Tour"; 'Friends'; 'Classic'; 'Disney Princess') the proportion of parts in the 5C and monochrome groups were each lower than the the proportion of all other parts. In no case was the proportion of all other parts >50%.

Across all themes the average saturation is 46.6% (SD = 7.3) and lightness is 50.7% (SD = 8). (Fig. 7) No outliers were detected and all but one result fell within 2∂ of the mean ('Star Wars' was marginally lower on saturation).

Four factors were chosen for further analysis, with multiple themes chosen to represent each. These were the Gender (Young Male/Young Female), Age (Infant/Middle/Adult), if it was based on a franchise

(Yes/No), and relationship to franchise media (LEGO/ Media).

Gender

The LEGO Group no longer indicates a specific gender for its themes. However, such inferences can still be made. For example by examining the gender representation amongst its characters, reviewing old press releases, or examining any related media.[5] While many sets remained gender neutral, for this analysis 'Ninjago', and the super hero themes ('DC', 'Marvel') were considered targeted at a young male (YM) demographic, while 'Friends' and 'Disney Princess' were targeted at a young female (YF) one.

Minimal difference was noted in regards to the 5C%, S%, or L% between the sets targeting YM vs. YF (<5%). However a large (23.6%) difference was

Fig. 7 - Representation of saturation (top) and lightness (bottom) distribution with static hue

5 Ultimately the distinctions were made by the author

noted in the amount of parts used from the monochrome group, with YM at 55.3% and YM at 31.7%. This difference was made up for in other%, with an average of 22% for YM and 41.9% for YF. This demonstrates that the themes targeted towards the YF demographic use a much wider pool of colours.

In regards to the colours themselves, the YM targeted themes all have 'Red' and 'Blue' in their top colours, with 'Yellow', 'Tan', and 'Reddish Brown' also featuring. These colours make up the bulk of colours across all themes (Excl. the monochrome group). For the YF themes, 'Reddish Brown' and 'Tan' appear in both, and 'Yellow' is the only other colour appearing amongst the most common colours overall. This suggests that The LEGO Group is taking steps to create themes explicitly tailored to the YF demographic, whereas the YM demographic is encapsulated by LEGO's more general design philosophy.

Age

LEGO sets only provide a minimum suggested age, and often different sets within the same theme will have different ages. A future analysis can be undertaken to provide more granular results. However for the purposes of this paper several themes were selected to represent broad age demographics. 'Duplo' for the youngest age demographic (Infant), 'Creator' and 'City' for the middle demographic (Middle), and 'Architecture' for the oldest demographic (Adult).

The most striking result of this comparison is the rapid decrease of saturation with age. While lightness maintained a similar range, saturation fell from 56% for Infant, to 43.7% for Middle, to 33.3% for Adult. This suggests that, like the YF demographic discussed above, that The LEGO Group has a design approach specifically tailored to this demographic seperate from its generic philosophy.

There is little that stands out for the specific colours. The Middle demographic uses colours with the highest population amongst all parts, whereas both the Infant and Adult demographics deviate from this.

Internal/External

Unlike the previous two sections, there is little subjectivity as to which themes are designed in-house vs those that partner with a franchise. However upon examination of the results, no differences were noted between the two categories, with an ~1 point difference in all measures.
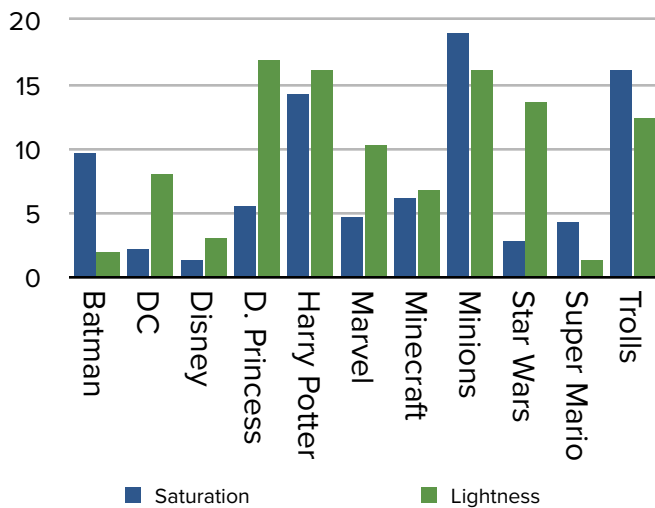
Franchises

Three metrics were considered when comparing the franchise media with its respective LEGO theme: the difference in average saturation (ΔS), in average lightness (ΔL), and the number of colour matches (CF%).

The average ΔS for across all franchised themes was 7.8, and the ΔL slightly higher at 9.7. When factoring direction of change, the results become -6.7 (ranging from -18.8 to 2.8) and -4.7 (range -16.9 to 16.1) respectively. i.e. the franchise media was, on average, less saturated and less light than its LEGO counterpart. 8/11 themes had franchise media with a lower saturation, 7/11 for lightness. From this we can say that LEGO uses more saturated colours than found in the franchise media, with the same assertion being made in a weaker form regarding lightness.

Examining individual themes, 'Disney' and 'Super Mario' had a <5 point difference in both saturation and lightness compared to their franchise media. 'Batman', 'Star Wars', 'DC', and 'Marvel' each had either saturation OR lightness with <5 points difference. 'Minions' fared the worst, with >15 points on both categories. 'Disney Princess', 'Harry Potter', and 'Trolls' each had only one category >15 points. (Fig. 8)

Fig 8. Difference in Saturation and Lightness: K-means vs LEGO

When comparing the list of colours sampled from the franchise media to those that appear in the LEGO themes (5C + monochrome), themes averaged a 39.1% match. 'Minecraft', 'Minions', and 'Trolls' only had a single colour match, whereas 'Disney Princess' and 'Harry Potter'[6] had >5. (Fig. 9).

The initial assumption was that colours associated with a franchise would be equally as prominent in the franchise media as they would be in a LEGO theme. While this may be the case, this analysis is unable to speak to the veracity of the claim. Upon examining all themes to see what colours were being matched, 'Light Bluish Gray' was matched 8 times, 'Tan' 6, 'Reddish Brown' 4, and 'Red'/'Dark Tan'/ 'Black' 3 each. The only notable exception to this is the 'Disney Princess' theme that, excluding the colours mentioned above, matched with additional 4 colours. Overall, it can not be concluded that the colour matching between these two datasets is significant.

5. Conclusion

This paper examined what factors may be involved in determining the colour palette of a LEGO theme. It used LEGO data downloaded from

Rebrickable, as well as a k-means sampling of media related to franchises that a number of LEGO themes represent. This data was collated, sorted, and summarised to provide information on the most common colours in a theme, the average saturation and lightness of its parts, and the differences and similarities with its respective franchise media.

Four broad categories were examined further based on the data that was collected: Gender, Age, In-House vs. Franchised, and Relationship to Franchise Media. While no evidence of significant difference was found based on whether a theme was franchised or not, some relationships were found for the other three categories.

Within Gender and Age, LEGO maintains the status quo of its overall trends when creating themes for males in the middle age demographic, using a large proportion of 'monochrome' colours (>50% of all parts) and colours most commonly found across all LEGO themes (e.g. 'Red', 'Tan', 'Blue'). This suggests that this group is their primary demographic. Infant, adult, and female targeted themes were each found to have colour palettes significantly different to the 'standard' LEGO themes, presumably in an effort to reach these demographics.

Fig. 9 -Colour Matching k-means vs LEGO

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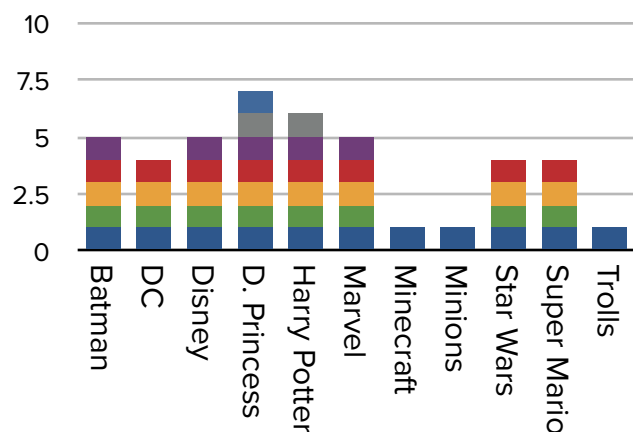
[6] Surprising given it had some of the largest difference in saturation and lightness

There was a notable decrease in saturation in relation to the age demographic of the theme, dropping from 56% average for the youngest group to 33.3% for the oldest. No trends were noted for lightness.

Saturation differences were also present when comparing LEGO themes to the franchises they represent. On average, saturation was 6.7 points higher in the LEGO than in the media, and of the three themes that had a lower saturation, none exceeded a 3 point difference. A similar, albeit less significant, result was seen regarding lightness.

The direct matching of colours between LEGO and the franchise media yielded some results, but none that matched the assumptions. The theme-franchise pairs that best matched were those where both contained a high amount of grey, black, or tan, rather than a more unique set of colours. This is likely due to decisions that both the theme and the franchise made independently of one another, rather than an intentional decision when translating between mediums. This comparison was also the most fraught with challenges (See below)

Limitations

Spherical LEGO in a Vacuum

Ultimately, this paper makes the assumption that all LEGO parts are equal. Two keys facts challenge this assumption.

The first is that LEGO parts come in a wide variety of shapes and sizes, ranging from as small as 8mm across for a 1x1 brick through to 380mm for a standard baseplate. The available data makes no effort to quantify a universal measure for the size of a LEGO part, and the creation of one was deemed beyond the scope of this paper.

The second is the visibility of the parts. Many LEGO parts, especially in black, are designed solely as connectors and are not typically seen on a finished model. On the other hand, other parts exist as one sided plates whose purpose is to be attached externally to the model. While such cases might be easily quantified, many parts exist somewhere in between. Potential lies in an analysis of LEGO instruction manuals but that would be a project unto itself.

Franchise, Colour, & k-Means

Due to the limits of available computing power, only a small number of materials were selected and sampled[7] to represent each franchise. However many of the limitations this analysis are unlikely to be solved by expanding the breadth of material collected.

Movie posters are not always the best representation of the key colours of a franchise. For example the posters available for the 'Minions', which do feature the titular yellow characters, feature a large amount of white space that skews the algorithm. Another is 'Trolls' which leans heavily on rainbow motifs which are difficult for k-means to parse. If the sampling was expanded to the entire film a better grasp might be made as to the overall saturation and lightness, but colour itself remains complex.

A better approach would be to more directly relate the sets within a theme to the parts of the franchise they represent as often sets are designed with key characters, object, or events. For example, the colours for a LEGO Death Star would be better compared to its representation in the movie than to the franchise as a whole. Unfortunately such an analysis would be considerably time consuming.

Ultimately, this process is not recommended for future research.

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[7] For information regarding the general limitations of a k-means sampling, see (Google, 2021)

Future Work

Past, Present, Future

For as much as LEGO has stayed the same since its inception, a lot has changed. Colours go in and out of production, themes come and go, and styles change. This is why this paper chose to focus on the last five years. With some refining of the model, it would be possible to see not only the way colours have been throughout the history of LEGO, but also how they've changed.

Prescriptive, not Descriptive

The work done in this paper has mostly worked to describe LEGO in its current state. However, an interesting approach would be to examine it from the opposite direction, and see what rules might be determining the colour choices. While doing so for the in-house themes might be challenging, there is potential to create a model for how a franchise might represent itself in LEGO form.

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