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Wayfinding in the Irchelpark

How does map completeness influence navigation performance?

Abstract

Wayfinding describes how people orient themselves and navigate through an environment, with map design playing a key role through elements such as color, landmarks, and level of detail. This study investigates how the completeness of a map influences wayfinding behavior in the Irchelpark, Zurich. A field experiment was conducted with eight participants unfamiliar with the area, who were divided into two groups with similar spatial orientation abilities. One group used a complete, detailed map, while the other used a simplified map with fewer visual elements. Wayfinding behavior was assessed using navigation time, GPS tracks, and a short questionnaire, allowing for a comparison of navigation performance and user experience between the two map types and offering insights into context-dependent map design.

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Introduction

Wayfinding is a complex process that involves multiple different variables (Farr, 2012). Furthermore, effective map design depends on the context of its use and its environment (Griffin et al., 2017). Our study wants to investigate how the completeness of a map influences the wayfinding behaviour of people in the Irchelpark. To do this, we created two different maps with varying degree of completeness. One is purposely lacking colour and some landmarks like the Irchelpond, as well as general level of detail. Both maps were assigned to a group of four people each, that had to find a certain point in the Irchelpark. To measure if there is a difference in wayfinding performance between the two groups, the time and GPS track of the different participants were measured. The goal of the study is to have a better understanding of how map design influences wayfinding behaviour in general and what level of completeness seems to be better for wayfinding tasks in the environment of the Irchelpark. This helps map-designers make future maps for similar purposes.

To do this, we have formulated the following research question:

How does the completeness (color, landmarks, level of detail) of a map influence wayfinding performance in the Irchelpark in terms of search time and taken track?

As we expect the group with the complete map to perform better, we have formulated the following working hypotheses:

H1: Participants using the complete map will reach the destination faster.

H2: Participants using the complete map will make less detours (smaller sinuosity).

H3: Participants using the complete map will have a better user experience and (subjectively) perceive it as better.

Literature Review

This section is introducing literature on wayfinding related to map design. A special emphasis lies on parameters color, landmarks and level of detail that were varied between the complete and the simplified map in this study. Yesiltepe et al. (2020) state that Landmarks are one of the most important features in wayfinding activities. Landmarks can help finding a location and also when to change direction on a path (Yesiltepe et al., 2020). Also, Cheng & Pérez-Kriz (2014) found that landmark knowledge helps for location and that landmarks are from particular importance in wayfinding. Also, in the concept of the cognitive map, landmarks play a big role. Epstein et al. (2017) state that physically larger landmarks, as well as landmarks at spatial decision points have a larger influence on the cognitive map. Soh & Smith-Jackson (2004) studied the influence of color coding in map design on wayfinding performance. They stated that color maps are better for discriminating map features in outdoor areas. Without colors, water features like lakes or rivers are difficult to discriminate from different map elements (Soh&Smith-Jackson, 2004). However, Devlin & Bernstein (1997) found in their experimental design on wayfinding that color and level of detail didn’t make a difference on the participant’s wayfinding efficiency. Less detail in a map may even have some benefits in wayfinding, depending on the exact usage (Devlin & Bernstein, 1997). Also, Soh & Smith-Jackson (2004) conclude that less map detail may lead to better legibility on a small-scale map to avoid cluttering effects.

Methods

This study consists of a field experiment in the Irchelpark with a between-subject design of two groups. In total we had a number of eight participants in our study. Before we could form the groups, the participants were tested on their spatial orientation abilities by the Santa Barbara Sense of Direction (SBSOD) test. This is a self-report test on spatial cognition that predicts spatial ability based on own participants own self-assessments (Hegarty et al., 2002). Based on the received SBSOD scores two groups A and B were formed manually that had the same score of 4.92 in average. So, it can be assumed that both groups have about the same spatial abilities overall. Group A received a complete map of the Irchelpark. Group B received a map of exactly the same area but in a simplified version with less features. So, the independent variable in this experimental setup is the map type received. The exact differences of the two maps are explained later on. Our measurements consisted of the GPS-track of every participant's route, the time the participants needed to reach the destination and a questionnaire that was conducted after reaching the destination. From the GPS-track we then also derived the Sinuosity to have a measure of the deviation from the straight line. To take the walking speed of the participants into account as well, we measured how long it took them to walk 100 meters on a separate path and normalized the measured time with their walking speed. The used formula looked the following:

$$time_{normalized} = time_{initial} \times \left(\frac{100m\_times_{mean}}{100m\_times_{individual}}\right) \qquad \textit{(Eq.1)}$$

Participants with slow walking speed then got multiplied with a factor higher than 1 and participants with fast walking speed with a factor lower than 1. The questionnaire consisted of the following four questions regarding the wayfinding experience and the map itself:

1. *How hard was it for you finding the right track?*
2. *What helped you orient yourself?*
3. *How good was the map in your opinion?*
4. *What would you change about the map?*

The dependent variables in this experiment are the time of reaching the destination, the measured GPS-track with the derived sinuosity and the answers of the questionnaire. The study sample consisted of eight participants that have never been to the Irchelpark before and therefore were unfamiliar with the environment. The participants were primarily students from the University of Zurich and ETH Zurich from faculties other than geography who haven't been to the Irchel Campus before, as well as non-students. All participants were between 20 and 30 years old.

The participants all started at the Milchbuck tram stop at the small water fountain. They received the map printed out in paper and were shown where they are and the destination they have to reach (the seating area at Monte Diggelmann). The participants were advised to walk there as direct as possible with their normal walking speed. They weren't allowed to ask anyone on their way. The time was recorded as soon as they received the map and got the instructions. One of us was waiting at the destination and stopped the time when they got to the desired destination. After reaching the destination the participants answered the questionnaire, and their walking speed was measured on a straight 100-meter distance.

The two maps can be seen below with the complete map on the left and the simplified map on the right. The two maps were designed based on the findings in the literature review. The emphasis laid on the aspect's landmarks, color and level of detail which have been varied to detect if the group with the complete map performs better in wayfinding tasks.

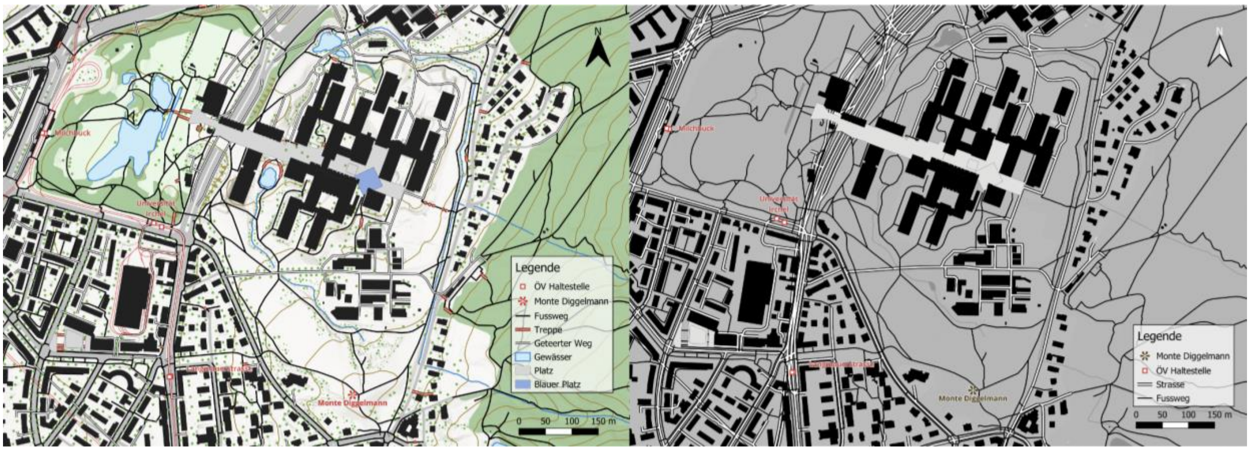

Figure 1. the complete map (left) and the simplified map (right). The maps can also be found separately in the appendix.

The analysis of the data sampled in the field is done in RStudio. The recorded tracks have been inspected for errors, and afterwards combined into a single file, with separate attributes specifying the user and the group (map type). Then, the data could be loaded into RStudio, to compute basic metrics like time, distance and raw speed between the track points. Afterwards, the normalization was applied, using the formula in figure 2. As a last metric, the sinuosity of the tracks were calculated. In order to display the important data, a summary of all metrics was made, and with that a few boxplots. In addition to the numbers, a Wilcoxon rank sum test was done, once for the normalized track times, and once for the sinuosity.

The Wilcoxon rank sum test was chosen, as we want to find out, whether there is a difference between two groups. In addition, our metrics (time, sinuosity) are on the interval scale, and we have a small sample size, meaning we need a test that suits data, that isn't normally distributed. The complete script can be found in the appendix.

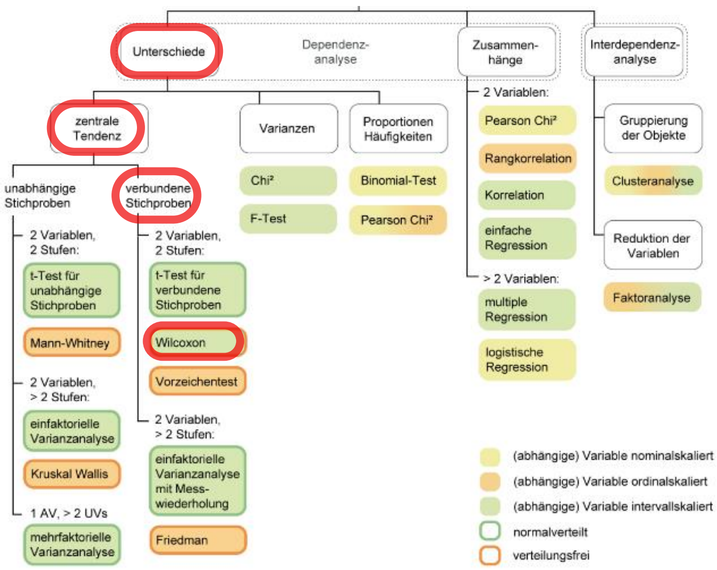

Figure 2: Decision-chart for appropriate statistical test.

Results

Table 1: Summary of all metrics.

pid	Map type	distance [m]	time [s]	time [min]	100m-time [s]	normalized time [s]	normalized time [min]	sinuosity
A1	complete map	848	652	10:52	58	715	11:55	1.16
A2	complete map	1080	772	12:52	60	819	13:39	1.427
A3	complete map	952	738	12:18	64	734	12:14	1.301
A4	complete map	951	611	10:11	53	733	12:13	1.266
B1	simplified map	930	648	10:48	74	557	09:17	1.199
B2	simplified map	1175	890	14:50	69	821	13:41	1.526
B3	simplified map	915	702	11:42	69	647	10:47	1.18
B4	simplified map	924	614	10:14	62	630	10:30	1.214

The distances of the paths range from a minimum of 848m in the group of the complete map, up to 1175m in the group of the simplified map. The times, before normalisation range between 611s to 772s for the complete map group, and between 614s to 890s for the group with the simplified map. The 100m times recorded for the normalisation range from 53s to 74s. The normalised times now range from 715s to 819s for the group with the complete map, and from 557s to 821s for the group with the simplified map. The sinuosity for the complete map group ranges from 1.16 to 1.427, and from 1.18 to 1.526 for the simplified map group (Table 1). Boxplots showing the navigation time, the normalized navigation time and the sinuosity as a comparison between the group with the complete map and the group with the simplified map are shown in Figure 3, to visually display the distribution of the metrics.

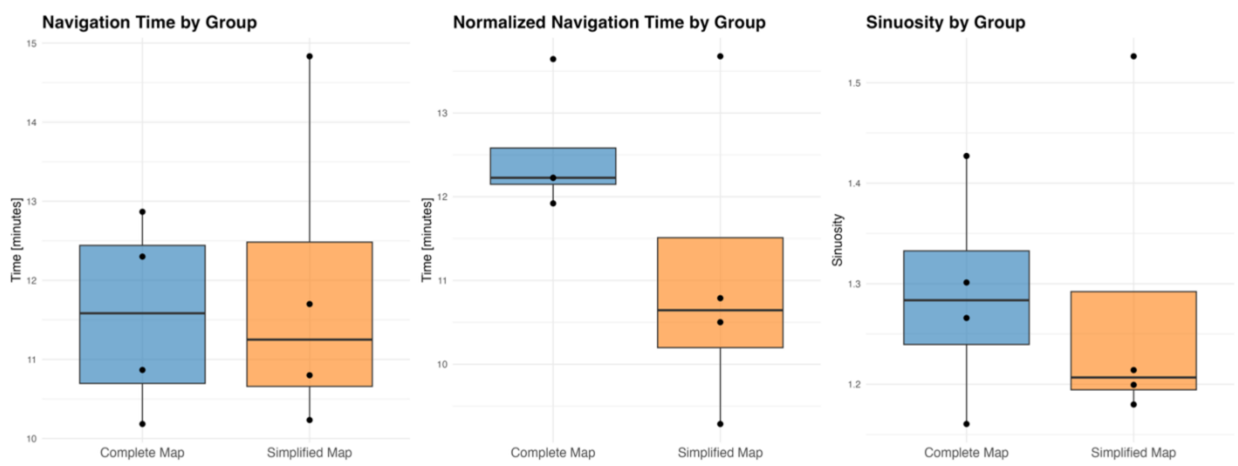

Figure 3: Boxplots comparing the number between the two groups (complete vs. simplified map).

With the normalized time and the sinuosity, we performed a Wilcoxon rank sum test, to assess whether there is a significant difference between the two groups (complete vs. simplified map). For the normalised time, we get a p-Value of 0.3429 (Fig. 4), and for the sinuosity, we get a p-Value of 0.8857 (Fig. 5). With those being bigger than 0.05, it can be said that there is no significant difference between the group with the complete and the simplified map, in terms of normalised navigation time as well as for the sinuosity of the tracks.

```
        Wilcoxon rank sum exact test

data:  total_time_norm_sec by group
W = 12, p-value = 0.3429
alternative hypothesis: true location shift is not equal to 0
```

Figure 4: Wilcoxon rank sum test for normalised navigation time. No significant difference between groups with p-Value of 0.3429 > 0.05.

```
        Wilcoxon rank sum exact test

data:  summary_df$sinuosity by summary_df$group
W = 9, p-value = 0.8857
alternative hypothesis: true location shift is not equal to 0
```

Figure 5: Wilcoxon rank sum test for sinuosity. No significant difference between groups with p-Value of 0.8857 > 0.05.

Figure 6 shows a map of the tracks the participants of each group have taken. Most of them are close together, with a few outliers.

Figure 6: Map showing the recorded tracks. Violet tracks taken by participants with the simplified map, and green track taken by participants with complete map.

In order to assess the user experience, we asked three questions. In general, all participant, no matter the map type, stated that finding the right track was rather easy. Only one person found the difficulty to be medium (Fig. 7).

When asking about their perception regarding the goodness of the maps, for the complete map group, 3 participants found the map generally good, and one participant found it okay. In the simplified map group, all participants stated that they found the map just okay, nod specifically good, but neither really bad (Fig. 8).

When it comes to what they would change about it, in the group with the complete map, only one person had something in mind, which would be adding the street names. The other 3 wouldn't add something. In the group with the simplified map, all 4 participants stated that they would add colours. In addition, they would have like additional information and more details, like highlighting the forest, displaying the waterbodies, and characterising the different types of paths.

„How hard was it for you, finding the right track?" ***«How good was the map in your opinion?»***

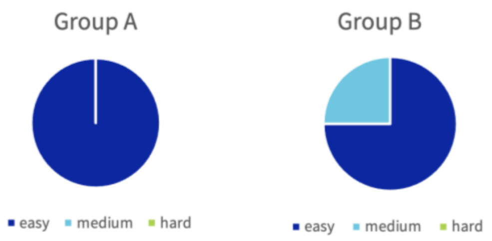

Figure 7: Result of survey question about track finding difficulty. Group A corresponds to group with complete map, and Group B to simplified map.

Figure 8: Result of survey question about map quality. Group A corresponds to group with complete map, and Group B to simplified map.

Based on those results, we are able to answer our question. We cannot accept H1 and H2, meaning there is no significant difference between the two maps, regarding the wayfinding performance (time, sinuosity) (Fig. 4, 5). But we could observe a difference when it comes to the user experience, which clearly was better for the complete map (Fig. 7, 8). Therefore, the results only follow our hypotheses to a certain extent, and despite the noticeably better impression of the complete map along the participants, the extension of this image onto the performance was missing.

Discussion

The aim of this study was to examine how map completeness, including color, landmarks, and level of detail, influences wayfinding in the Irchelpark. The study focused on objective wayfinding performance, measured by normalized travel time, route sinuosity and subjective user experience. The central research question asked whether a more complete map leads to better wayfinding outcomes compared to a simplified map. The results show that there is no statistically significant difference between the two groups in terms of time or sinuosity. Participants using the complete map did not reach the destination faster, nor did they take more direct routes than participants using the simplified map. Therefore, hypotheses H1 and H2 could not be accepted. These findings are consistent with Devlin and Bernstein (1997), who also found that color and level of detail do not necessarily improve wayfinding efficiency. At the same time, the results differ from studies emphasizing the importance of landmarks and color for navigation, such as Yesiltepe et al. (2020) and Soh and Smith-Jackson (2004).

A possible explanation for this outcome lies in the characteristics of the study area. The Irchelpark has a clear and well-defined path network that naturally guides movement. Participants could simply follow the visible paths without needing frequent reference to the map. Because the task was performed at walking speed, participants had enough time to orient themselves even with limited map information. In this context, additional details such as color or landmarks did not provide a measurable advantage for navigation performance. This situation differs from navigation contexts with higher speed or complexity, such as car navigation or dense urban environments. In such settings, users cannot constantly look at the map, and visual cues like landmarks, colors, and clear symbols become more important for quick orientation. In the Irchelpark, however, the physical environment already provided strong guidance, reducing the functional importance of detailed map design.

In contrast to the objective measures, the subjective evaluation of the maps showed a clear difference. Participants using the complete map rated it more positively and reported fewer problems. Participants using the simplified map consistently asked for more colors, clearer background information and better differentiation of elements such as paths and water features. Based on these results, hypothesis H3 was accepted. This supports previous findings that map design strongly affects user confidence and perceived quality, even if performance outcomes remain unchanged. These results highlight the difference between efficiency and user experience. Although both maps were sufficient to reach the destination, the complete map made participants feel more comfortable and better oriented. This suggests that good map design is not only about helping users arrive at a destination, but also about reducing uncertainty and increasing confidence during navigation.

Several limitations should be considered. The small sample size limits the statistical power of the study and may have prevented the detection of small effects. In addition, the experiment was conducted in a single, relatively simple environment. The participants were also similar in age and background, which further limits generalization. Results may differ in more complex environments or with more diverse user groups. Future research should include larger samples and different types of environments, such as urban areas or spaces without clear paths. It would also be useful to study navigation under time pressure or at higher movement speeds. Combining GPS data with more detailed questionnaires or behavioral observations could provide deeper insights into how users interact with maps.

Conclusion

This study aimed to assess the influence of map design on navigation performance. We wanted to find out, if there is a difference in navigation performance, depending on the map that is used. To answer our question, we made a field experiment following a between-subject design with two groups, consisting of four participants, respectively with a complete and a simplified map. Participants of both groups were advised to navigate to a certain point on the map. The tracks have been recorded, as well as their walking speed with a short survey in addition.

The main findings are, that there was no significant difference, in terms of navigation time, as well as track sinuosity. Suggesting that in our case, and in the experimental setting we chose, there is no significant difference between the two map types. In contrast to that, the qualitative analysis based on the survey and the experience of the participants showed a clear difference. It showed that the participants with the complete map have been more satisfied with it, compared to the group with the simplified map. On top of that, very interestingly, all the suggested things and add On's, suggested by the participant with the simplified map, were almost exactly what we have done in our complete map.

But we also encountered some limitations. The most obvious one, is the small number of participants and the generally limited extent of the experiment. Even if there would have been a significant difference, the sample size would have been too small in order to identify a valid trend and potential patterns. Then, the study area itself may be a problem, since it already pushes participants into a certain direction (due to terrain etc.). To address those limitations, further studies have to be done, with more participants and a more ambiguous terrain. In addition, it would be very interesting to assess whether there is a difference between fast and slow speeds, and what elements make a significant difference for which use case.

Literature

Cheng, Karen; Pérez-Kriz, Sarah (2014): Map Design for Complex Architecture: A User Study of Maps & Wayfinding. Visible Language, 48:2, 6-33.

Devlin, Ann Sloan; Bernstein, Jason (1997): INTERACTIVE WAY-FINDING: MAP STYLE AND EFFECTIVENESS. Journal of Environmental Psychology, 17, 99-110.

Farr, Anna Charisse; Kleinschmidt, Tristan; Yarlagadda, Prasad; Mengersen, Kerrie (2012) Wayfinding: A simple concept, a complex process, Transport Reviews, 32:6, 715-743.

Griffin, Amy L., White, Travis, Fish, Carolyn, Tomio, Beate, Huang, Haosheng, Robbi Sluter, Claudia, Meza Bravo, João Vitor, Fabrikant, Sara I., Bleisch, Susanne, Yamada, Melissa & Picanço, Péricles (2017). Designing across map use contexts: a research agenda. *International Journal of Cartography, 3*:1, 90–114.

Hegarty, M., Richardson, A. E., Montello, D. R., Lovelace, K., & Subbiah, I. (2002). Development of a self-report measure of environmental spatial ability. *Intelligence*, *30*(5), 425-447.

Soh, Boon Kee & Smith-Jackson, Tonya L. (2004): Influence of Map Design, Individual Differences, and Environmental Cues on Wayfinding Performance , Spatial Cognition and Computation, 4:2, 137-165.

Yesiltepe, Demet; Dalton, Ruth Conroy; Torun, Ayse Ozbil (2021): Landmarks in wayfinding: a review of the existing literature. Cognitive Processing, 22, 369-410.

Appendix

RStudio code:

```
library(dplyr)
library(geosphere)
library(ggplot2)
library(lubridate)
library(readr)
library(stringr)
library(patchwork)

# ------------------------------------------------------------
# 1. Load raw dataset
# ------------------------------------------------------------
df <- read_csv("~/Desktop/Cognitive Issues/GEO873/good_stuff/all_tracks_corrected.csv", show_c
ol_types = FALSE)

# Ensure types:
df <- df %>%
  mutate(
    timestamp = as.POSIXct(paste(date, time), tz = "UTC"),
    participant = as.character(participant),
  ) %>%
  arrange(pid, timestamp)

# ------------------------------------------------------------
# 2. Compute time differences per point
# ------------------------------------------------------------
df <- df %>%
  group_by(pid) %>%
  arrange(timestamp, .by_group = TRUE) %>%
  mutate(
    dt_raw = as.numeric(difftime(timestamp, lag(timestamp), units = "secs"))
  ) %>%
  ungroup()

# Replace NA for first row per participant
df$dt_raw[is.na(df$dt_raw)] <- 0

# ------------------------------------------------------------
# 3. Compute Haversine distance between consecutive points
# ------------------------------------------------------------
df <- df %>%
  group_by(pid) %>%
  mutate(
    distance_m = distHaversine(
      cbind(lag(longitude), lag(latitude)),
      cbind(longitude, latitude)
    )
  ) %>%
  ungroup()

df$distance_m[is.na(df$distance_m)] <- 0

# ------------------------------------------------------------
# 4. Compute raw speed (km/h)
# ------------------------------------------------------------
df <- df %>%
  mutate(speed_raw_kmh = ifelse(dt_raw > 0, (distance_m/1000) / (dt_raw/3600), 0))

# ------------------------------------------------------------
# 5. Normalization factors based on 100m times
# ------------------------------------------------------------
hundred_m_times <- c(
  A1 = 58, A2 = 60, A3 = 64, A4 = 53,
```

```r
  B1 = 74, B2 = 69, B3 = 69, B4 = 62
)

mean_100m <- mean(hundred_m_times)

df$norm_factor <- mean_100m / hundred_m_times[df$pid]

# -------------------------------------------------------------
# 6. Apply normalization to time and speed
# -------------------------------------------------------------
df <- df %>%
  mutate(
    dt_norm = dt_raw * norm_factor,
    speed_norm_kmh = ifelse(dt_norm > 0, (distance_m/1000) / (dt_norm/3600), 0)
  )

# -------------------------------------------------------------
# 7. Compute Sinuosity per participant
# -------------------------------------------------------------
compute_path_length <- function(lat, lon) {
  pts <- cbind(lon, lat)
  seg <- distHaversine(pts[-nrow(pts),], pts[-1,])
  sum(seg, na.rm = TRUE)
}

sinuosity_df <- df %>%
  group_by(pid, group, participant, map_type) %>%
  summarise(
    start_lat = first(latitude),
    start_lon = first(longitude),
    end_lat   = last(latitude),
    end_lon   = last(longitude),
    actual_path_m = compute_path_length(latitude, longitude),
    straight_m = distHaversine(
      c(first(longitude), first(latitude)),
      c(last(longitude),  last(latitude))
    ),
    sinuosity = actual_path_m / straight_m,
    .groups = "drop"
  )

# -------------------------------------------------------------
# 8. Summary per participant
# -------------------------------------------------------------
summary_df <- df %>%
  group_by(pid, group, participant, map_type) %>%
  summarise(
    total_time_sec       = sum(dt_raw),
    total_time_norm_sec  = sum(dt_norm),
    total_distance_m     = sum(distance_m),
    .groups = "drop"
  ) %>%
  left_join(sinuosity_df, by = c("pid", "group", "participant", "map_type")) %>%
  mutate(
    hundred_m_time_sec = hundred_m_times[pid],
    # Convert to mm:ss format
    time_mmss      = sprintf("%02d:%02d", total_time_sec %/% 60, round(total_time_sec) %% 60)
,
    time_norm_mmss  = sprintf("%02d:%02d", total_time_norm_sec %/% 60, round(total_time_norm_s
ec) %% 60),
  )

print(summary_df)
write_csv(summary_df, "~/Desktop/summary_with_sinuosity.csv")
# -------------------------------------------------------------
# 9. Wilcoxon rank sum test (on normalized time)
```

```r
# -----------------------------------------------------------
wilcox_res <- wilcox.test(summary_df$total_time_norm_sec ~ summary_df$group, data = summary_df
)
print(wilcox_res)

wilcox_res <- wilcox.test(summary_df$sinuosity ~ summary_df$group, data = summary_df)
print(wilcox_res)

# -----------------------------------------------------------
# 10. Create visualizations
# -----------------------------------------------------------

# Total normalized time by group
p1 <- ggplot(summary_df, aes(x = group, y = total_time_norm_sec/60, fill = group)) +
  geom_boxplot(alpha = 0.6) +
  geom_point(size = 2, position = position_nudge(x = 0)) +
  labs(
    title = "Normalized Navigation Time by Group",
    x = "Group",
    y = "Time [minutes]"
  ) +
  scale_fill_manual(
    values = c("A" = "#1f77b4",   # new colour for group A
               "B" = "#ff7f0e"),  # new colour for group B
    labels = c("A" = "Complete Map",
               "B" = "Simplified Map")
  ) +
  scale_x_discrete(
    labels = c("A" = "Complete Map",
               "B" = "Simplified Map")
  ) +
  theme_minimal()
print(p1)

# Sinuosity by group
p2 <- ggplot(summary_df, aes(x = group, y = sinuosity, fill = group)) +
  geom_boxplot(alpha = 0.6) +
  geom_point(size = 2, position = position_nudge(x = 0)) +
  labs(
    title = "Sinuosity by Group",
    x = "Group",
    y = "Sinuosity"
  ) +
  scale_fill_manual(
    values = c("A" = "#1f77b4",   # new colour for group A
               "B" = "#ff7f0e"),  # new colour for group B
    labels = c("A" = "Complete Map",
               "B" = "Simplified Map")
  ) +
  scale_x_discrete(
    labels = c("A" = "Complete Map",
               "B" = "Simplified Map")
  ) +
  theme_minimal()
  p2

print(p2)

# Total time by group
p3 <- ggplot(summary_df, aes(x = group, y = total_time_sec/60, fill = group)) +
  geom_boxplot(alpha = 0.6) +
  geom_point(size = 2, position = position_nudge(x = 0)) +
  labs(
    title = "Navigation Time by Group",
    x = "Group",
    y = "Time [minutes]"
```

```
  ) +
  scale_fill_manual(
    values = c("A" = "#1f77b4",   # new colour for group A
               "B" = "#ff7f0e"),  # new colour for group B
    labels = c("A" = "Complete Map",
               "B" = "Simplified Map")
  ) +
  scale_x_discrete(
    labels = c("A" = "Complete Map",
               "B" = "Simplified Map")
  ) +
  theme_minimal()
print(p3)

# ------------------------------------------------------------
# 11. Combine Visualizations with Patchwork
# ------------------------------------------------------------

# p3 = Raw Time, p1 = Normalized Time, p2 = Sinuosity
combined_plot <- (p3 | p1 | p2) +
  plot_layout(nrow = 1) +
  plot_annotation(
    #title = "Navigation Performance Analysis",
    #subtitle = "Complete Map (Group A) vs. Simplified Map (Group B)",
    #caption = "Units: Time in minutes, Sinuosity as a ratio (actual/straight distance)."
  ) &
  theme_minimal() &
  theme(
    legend.position = "none",         # Removes the redundant color legends
    axis.title.x = element_blank(),   # Removes the "group" label from the bottom
    plot.title = element_text(face = "bold", size = 16),
    axis.title.y = element_text(size = 12), # Ensures Y labels are clear
    axis.text.x = element_text(size = 12)
  )

print(combined_plot)

ggsave(
  "~/Desktop/navigation_results_with_ylabels.png",
  combined_plot,
  width = 16,
  height = 6,
  dpi = 300
)
```

Figure 1: Simplified map.

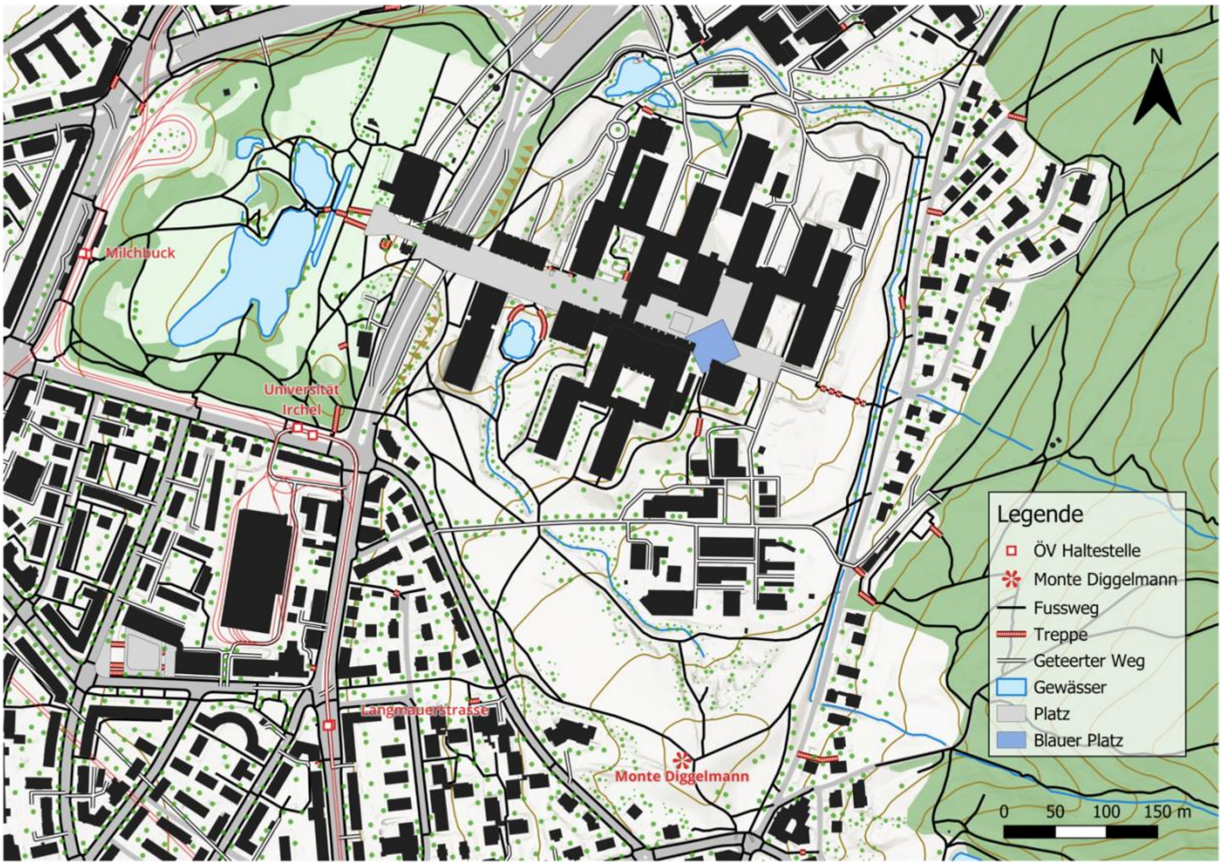

Figure 2: Complete map.